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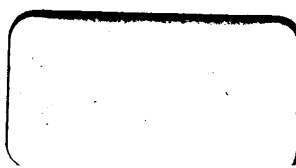

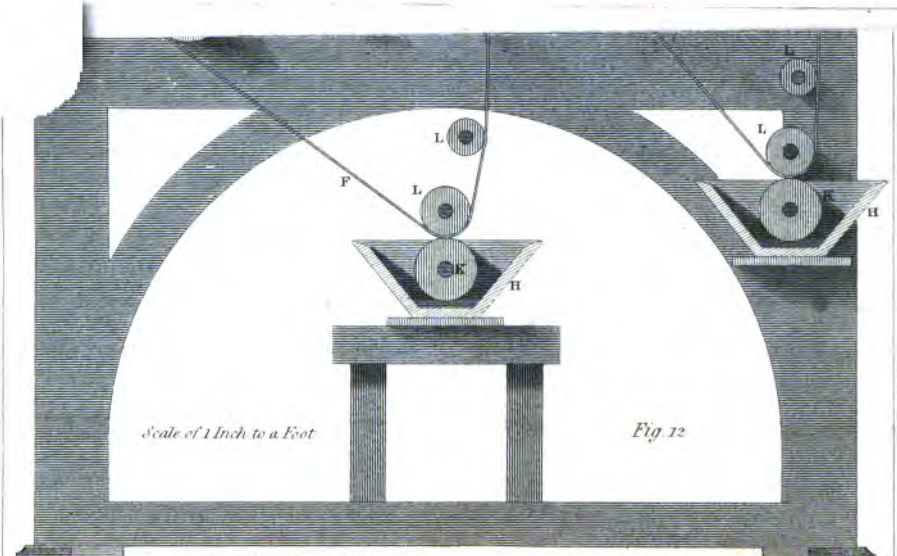

A. Parkinson del

Jos. Davis sculp.

CHEMICAL ESSAYS,

PRINCIPALLY RELATING TO

THE ARTS AND MANUFACTURES OF THE BRITISH DOMINIONS.

BY

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IN FIVE VOLUMES.

VOL. II.

LONDON:

PRINTED FOR THE AUTHOR: AND PUBLISHED BY BALDWIN, CRADOCK, AND JOY, PATERNOSTER ROW.

1815.

Chem 7108.15

Harvard College Library
Gift of
Miss Longfellow, Mrs. Dana,
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Feb. 19, 1897.

Entered at Stationers' Hall.

Richard and Arthur Taylor,
Printers, Shoe Lane.

DESCRIPTION OF THE PLATES

IN

THE SECOND VOLUME.

PLATE VI.

Mr. Parkinson's machine for printing three distinct colours at once on calico, referred to at page 173 of this volume.

A. A screw to give the proper pressure to the main roller. There is a similar one at the other end of the machine.

B. Screw to give the necessary pressure to the copper roller C.

C. A copper roller, with one of the patterns engraved on it. This receives the colour from a small box at the top, which could not be shown in the engraving.

D is the main roller of iron, round which the calico passes in order to receive the printed impression from the three smaller rollers C, G and G.

E. A wooden roller to guide the blanket, against which the white calico lies. This blanket could not be distinctly shown in the engraving.

F F. Two blankets to receive the colour from the two colour boxes H H. On these blankets the respective colours become by the rotary motion uniformly spread by the time they arrive at the rollers G G, on which these are to be deposited.

G G. Two wooden rollers with patterns cut upon them. Each of these, as before mentioned, receives the colour from the blanket F, which moves underneath, and immediately imparts it, in the desired pattern, to the white calico which revolves by an equable motion round the large iron roller D.

H H. Two wooden troughs containing the prepared colour. These the workmen call *colour boxes.*

L is an opening for filling the reservoir, occasionally cleansing it out, &c.

M M M the agitator for constantly stirring the alkaline solution, and which is necessary to promote the absorption of the gas. In large works this is moved by a power from the steam engine.

N is the cock for drawing off the finished liquor as mentioned above.

The glass bottle, which appears in the same plate, contains two bubbles of glass; one is seen at bottom, the other floating on the surface of the liquor. This is recommended as a small and useful apparatus for ascertaining the specific gravity of the oxymuriate of soda. Its advantages, together with the mode of using it, are fully described in the Additional Notes, No. 82, vol. v. page 72.

PLATE XIX.

Is descriptive of an apparatus for bleaching cotton goods. Fig. 1 is a section of the bucking apparatus, which may be thus described.

A is the boiler for heating the alkaline lye.

B represents a very large wooden vessel in which the calicoes are placed.

C the cock and pipe, by means of which the hot lye is conveyed upon the goods.

D is a square box designed for spreading the lye over the calicoes within the vessel B.

E a pump for raising the liquor again out of the vessel B, from whence it is conveyed by the spout I back into the boiler A.

F is the furnace for heating the lye.

G represents the false bottom of the calico vessel, full of holes for the passage of the lye when it has run through the goods under operation.

H is a round wooden staff which completely fits a hole at the bottom of the bucking vessel. It is called a duck, and is intended to be pulled up whenever it is intended to run off the spent alkaline liquor.

I is the spout for conveying the liquor back to the boiler as above mentioned. In some houses the boiler is fixed below the bucking vessel, and the pump is placed within the boiler as described in vol. iv. note 33, page 31.

Fig. 2 is the representation of a common whale-boiler.

A is a metallic boiler to be fixed in brick-work, similar to that in fig. 1.

B B is the top part of wood, called a crib, with the bottom full of holes. In this the calicoes are placed one above another, often amounting to many hundred pieces at one operation.

C is the pipe through which the lyes boil up, and d d is the umbrella suspended over the pipe for the purpose of spreading the lyes more effectually as they fall down again upon the goods.

This apparatus for bleaching possesses several advantages. The perforated wooden vessel preserves the calicoes from being injured by coming in contact with the boiler, while the pressure occasioned by so great a weight of goods frequently increases the temperature of the lye by some degrees higher than it would acquire in an *open* vessel, and this additional heat has a powerful effect in bleaching. By this contrivance there is no necessity for pumping;

for, so long as the lye in the vessel A actually boils, a constant stream will flow through the pipe C upon the goods in B, and thus a perpetual circulation may be kept up till the goods have attained the desired whiteness.

PLATE XX.

Is descriptive of some peculiar modes of purifying water. Figs. 1, 2, and 3, represent a glass apparatus invented by Mr. Pepys for filtering small quantities of water or other fluid, and may be thus described.

Fig. 2 is a glass vessel with a rib of tinned iron going round the inside of it near the top. This rib has many notches upon it, and these are designed for receiving a number of small glass rods as shown in the drawing, fig. 1. These are intended for supporting a sheet of filtering paper or any other kind of filter which may be placed within the jar. When this vessel is charged with the liquor proposed to be filtrated, the cover d, which completely fits it, is put on to preserve the contents from dust or other accidental impurities.

position of Derbyshire cauk, or the common sulphate of barytes.

Fig. 1 is an elevation of the furnace, as it appears when finished. Fig. 2 is as it appears before the arches are turned over it.

A is the ash pit. B the fire-place, with the fire bars. C the bottom of the furnace on which the ground cauk mixed with the carbonaceous matter is to be exposed to the action of the fire, with continual stirring. D is the chimney for carrying off the smoke, the sulphurous acid gas, and other incondensable products. E a door for emptying the ash pit. F the furnace arch and opening to repair the furnace. G the hopper for feeding the fire. H H the doors into the furnace for the convenience of stirring the materials, and through which the sulphuret of barytes is to be withdrawn when finished. I the arch of the fire-place.—For the method of using this furnace see page 244.

PLATE X.

Apparatus for making charcoal and distilling pyroligneous acid.

Fig. 1 represents a section of a charcoal cylinder when fixed within the furnace. It is cut lengthwise through the middle, to show the internal work.

Fig. 2 is a contrary section of the same cylinder, the end, or front wall being in this case taken away to show how the fire plays round it before it passes off by the chimney.

Fig. 3 is an elevation of the building which incloses a cylinder when properly fixed, together with the fire-place, the tubes to carry off the acid and gas, the wine casks to receive pyroligneous acid, &c. complete.

Fig. 4. The outer shutter, to contain the stopping or luting which makes the cylinder air-tight during the operation of distilling the acid and charring the wood.

Fig. 5. The inner shutter, or stopper to prevent the stopping from getting among the charcoal.

PLATE XI.

APPARATUS FOR MAKING COKE.

Fig. 1 represents the ground plan of one of the coke-ovens belonging to His Grace the

Duke of Norfolk, at Sheffield in Yorkshire, communicated by Mr. Curr, steward to His Grace in the year 1802.

The oven is built circular, with a wall of two bricks length, or 18 inches, in thickness. Its diameter is ten feet in the clear withinside, as will be seen by a reference to the scale.

A is the platform or floor of the oven, which is elevated three feet above the ground, as will appear from an examination of the elevation fig. 2. This is contrived for the convenience of placing a wheelbarrow under the door to receive the cokes as they are drawn from the oven.

B is the opening or door-way for drawing out the cokes. It is 2 feet wide and 19 inches high to the springing of the arch. This door-way has a broad cast-iron sill built into the wall when the furnace was erected.

C. The oven wall, which is 18 inches thick and 19 inches high, when measured from the floor of the oven. The diameter is then contracted, and the roof is brought in like a glass-house, to the height, when measured perpen-

dicularly, of 3 feet 5 inches more, leaving a circular opening of two feet diameter at the top, for supplying the furnace with the coals which are to be converted into coke, and to serve as a chimney when the coals are first ignited. The latter wall is only one brick's length in thickness, and the *ends* of the bricks are placed towards the fire. The floor is laid with hard common bricks on the edge; common bricks are also sufficient for the first wall of 19 inches high, but it is absolutely necessary to have good fire brick for the whole of the arch or covering.

D D is a wall built with common unhewn stone, about 20 inches thick, and carried up the whole height of the oven, the void spaces in the corners to be filled with soil or rubbish and well rammed. It may be observed that it would be economical to build a furnace of this kind on the side of a hill, with the space it occupies cut out of the bank. Care must, however, be taken to build it in such a way that no air shall enter through any of the brick-work into the body of the furnace.

Fig. 2 represents a front elevation of the coke oven, the ground plan of which has been described already.

In explaining this elevation, reference must be had to the letters engraven upon the plate.

C is intended to show the line of the oven floor.

D. The height of the oven-wall where the brick-work begins to contract.

E. The door-way for taking out the cokes when sufficiently burnt.

G G shows a section of the arched roof of the oven, but this is not seen in the front elevation, as the front wall and the backing of earth hide it.

The coke ovens are used thus:—Small coal is thrown in at the opening fig. 2, sufficient to cover the bottom of the oven 19 inches thick to the springing of the arch, which is about two tons; they are then levelled, and the door E built up with loose bricks. The heat of the oven sets the coal on fire, which is accelerated by the atmospheric air rushing in through the joints of the loose bricks in the door-way.

In the space of two or three hours the doorway is plastered up with a mixture of wet soil and sand, except the top row of bricks, which is left unplastered all night. This is generally plastered up close in about 24 hours after the coals are first put in, the chimney remaining open till the flame is gone, which is generally quite off in 12 hours more. A few loose stones are then laid over the chimney, and those covered up with sand or earth. After this is done, the cokes remain in the ovens 12 hours longer, and are then drawn out into wheelbarrows and carted away by the customers. The whole takes up 48 hours; and as soon as the cokes are raked out, the ovens are refilled with small-coal for another burning.

Fig. 3 represents a new mode of burning cokes in the open air by means of a large chimney round which the coals are piled. The method of managing this process is fully described at page 330.

PLATE XII.

A representation of the yard of a sulphuric-

acid manufactory walled entirely round, with all its requisite buildings and offices.

A A A A represent four chambers of combustion, made with sheet lead, each 50 feet long and 20 feet wide.

B is the main reservoir of lead, sunk within the ground for containing the weak acid from the chambers. It is 12 feet by 8 feet, and may be of any convenient depth.

C is a wooden trough, lined with lead, to convey the acid from the chambers of combustion to the reservoir. This trough should be always in its place; and when the operator wishes to empty the floor of any one of the chambers, he runs it off, by means of a syphon of glass or lead, into the trough, which conveys it without any loss into the reservoir.

D. A leaden pump fixed within the main reservoir, for supplying the five leaden boilers E with acid, as the contents of the said boilers become concentrated by evaporation of the water.

E E E E E. Five leaden pans, or boilers,

five feet by seven feet each, for concentrating the acid by steaming.

F is designed to mark nine pillars either of wood or bricks, for supporting the beam of a shed-roof, it being always advisable to erect such apparatus under a shed which is thus open on one side for the free access of atmospheric air, and the egress of the aqueous and sulphurous vapours which constantly arise from the boilers.

G. A reservoir, four feet by six feet, for containing the concentrated acid when it is run off from the steam boilers. This should have a close cover, to prevent the acid from becoming weak by absorbing water from the atmosphere.

H is a ground plan of the retorting-room, where the concentration is completed by boiling the acid, which has already been steamed in the vessels E in retorts of glass. This room is 50 feet by 20 feet.

I marks the situation of an open shed supported by pillars like the shed F already de-

scribed. This place is intended for packing the large glass bottles, or carboys as they are called, when filled with the sulphuric acid. It is 20 feet by 56 feet.

K. A warehouse for storing the bottles of oil-of-vitriol, after it is packed ready for sale. The size of this room is 20 feet by 70 feet.

L. The counting-house.

M. Store-room for salt-petre.

N. A store-room for brimstone.

O. The pounding-room, or place where the sulphur is ground and mixed with the nitre ready for combustion.

P is designed for a stable and cart-house.

Q is a small private room for keeping tests, instruments for taking specific gravities, and other things necessary for the use of the proprietors themselves.

R. The main entrance into the yard, with a covered lobby for the convenience of persons in waiting, and to prevent the introduction of improper people into the manufactory.

S is a circular building for coals. This is

placed in the centre for the convenience of supplying all parts of the manufactory.

T. A pump for supplying the lead houses with water.

U. Another pump for giving water to the yard in general, for washing bottles also, &c.

W is a large building for storing empty bottles, baskets, or other things belonging to the manufactory.

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ESSAY III.

ON

SPECIFIC GRAVITY.

ESSAY III.

ON

SPECIFIC GRAVITY.

NOTHING can be of more importance to those who are entering on the study of chemistry, or desirous of examining the works of nature with accuracy, than a competent knowledge of the most convenient methods of taking the specific gravity of bodies.

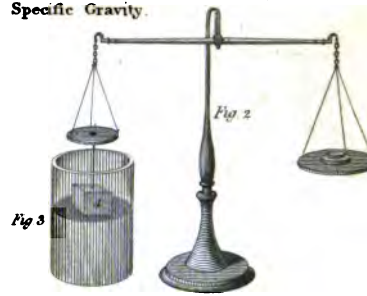
Every man of science who has had much intercourse with the world, must have met with many intelligent people who are entirely ignorant of this

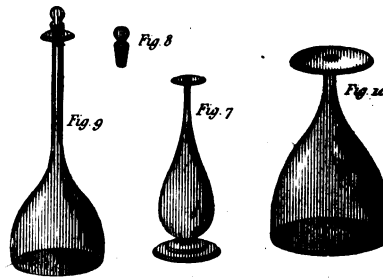
subject; and wherever this is the case, it must be a material obstruction to their making any considerable advances in chemical knowledge.

It may perhaps appear superfluous to those who are conversant with chemistry, to undertake to explain what they themselves so well know, that they cannot so much as recollect the time when it was not known to them. There are, however, many who are so entirely unacquainted with any of the modes of taking specific gravities, that they cannot even explain how absolute differs from specific weight: to such readers therefore no apology will be necessary.

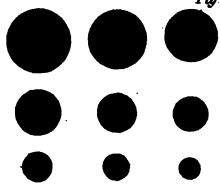
Gravity may be defined to be that

Specific Gravity.





Carat Weights



property inherent in all bodies which gives them a tendency towards the centre of the earth [1], and enables us to measure the quantity of matter in any particular mass, by means of the balance. The amount which the balance thus indicates is said to be the WEIGHT of that body. This is what we call the *absolute* weight, or the absolute gravity of any particular substance, to distinguish it from the *specific* weight; or, as it has some-

[1] "The quality by which all bodies tend towards the centre, accelerating their motion the nearer they approach towards it, true philosophy has shown to be unsolvable by any hypothesis, and resolved it into the immediate will of the Creator." Quincy.

times been called, its *comparative* gravity [2].

By SPECIFIC GRAVITY is meant the real weight of any substance when compared with an equal bulk of another, which we agree to call the standard; for which purpose all nations have fixed upon water as unity. Thus the specific gravity of one body may be less or greater than that of another, though their absolute weights may be the same.

The method of ascertaining quantities by means of the balance was known in the remotest ages [3]; but a

---

[2] The specific gravity of a body is in a direct ratio of the mass, and in an inverse ratio of its bulk.

[3] "Just balances and just weights shall ye

long period probably elapsed before mankind acquired any correct idea of distinguishing between the absolute and the comparative weight of bodies.

Even the great Archimedes[4], who

---

have, I am the Lord your God." Leviticus, xix. 36. "The spear-head of Goliath weighed six hundred shekels of iron." 1 Samuel xvii. 7. "Absalom weighed the hair of his head two hundred shekels after the king's weight." 2 Samuel xiv. 26. "Who hath weighed the mountains in scales, and the hills in a balance?" Isaiah xl. 12.

"Th' Eternal hung forth in Heav'n his golden scales
Wherein all things created first he weigh'd."

MILTON.

[4] See Essay I. on the Utility of Chemistry to the Arts, page 11; and Essay II. on Temperature, page 182, for some account of this very extraordinary man.

lived only in the third century before Christ, knew of no method of taking the specific gravity of the precious metals, so as to ascertain the amount of their adulteration; and it was only by long thought that he was at last enabled to succeed[5]. The mode which he devised is minutely described by Vitruvius[6], and his account has been translated for the General Biographical Dictionary, under the article "Archimedes[7]."

---

[5] When Archimedes had made himself acquainted with the nature of specific gravity, he wrote two books entitled "*de Insidentibus Humido*," of which the Latin translation is yet extant, though the original in Greek be lost.

[6] Architectura, lib. ix. cap. 3.

[7] Biog. Dict. vol. i. page 434.

On the revival of learning in Europe, we hear nothing of the examination of bodies by their specific gravities, until this was recommended by the Honourable Mr. Boyle, who showed the advantages which a student must derive in his examination of minerals, and in his other chemical pursuits, from the habit of paying a constant attention to this circumstance. Other philosophers of Britain then caught the idea, and the practice has been continued by a few illustrious men, such as Newton, Hales, Black, Lewis, Cavendish and Priestley; and now by all who make any pretensions to cultivate the sciences.

The introduction of this art must

have been considerably later on the continent of Europe; for one of the most esteemed French chemical writers tells us, that it was never employed with them in the analysis of minerals till the time of Buffon [8], who was the first to acknowledge its importance, and render it useful [9].

Specific gravity may be considered to be merely another term for the comparative density of bodies; and as

---

[8] This illustrious man, though opulent, spent fourteen hours a day in study. At five in the morning he retired to a pavilion in his vast gardens, and he was then inaccessible. Prince Henry of Prussia called this retreat the cradle of natural history.

[9] Fourcroy's System of Chemical Knowledge, vol. ii. page 359.

the nature and properties of a great variety both of solids and fluids depend in a great measure upon their density, nothing surely can be of more consequence in the examination of natural and artificial substances, than an attention to their specific gravities.

It is thus the purity of some of the metals, and the value of many liquid preparations are determined; and thus only can we decide the classification of some minerals when they are not subjected to a regular analysis.

To determine the purity of ammonia, the goodness of alcohol, the strength of other ardent spirits, and the concentration of the mineral acids, their

manufacturers entirely rely upon the respective indications which their specific gravities afford them.

In the preparation of alkaline lyes for the manufacture of soap, the operator has to determine the quantity necessary for each operation, and the specific gravity of the solution is his only guide. The makers of Roman vitriol, Epsom, Rochelle, Glauber, and other salts, have no proper criterion for ascertaining the strength of the several liquors which they have prepared for crystallization, but that of the specific gravity.

The strength of a variety of metallic solutions, and the concentration of many of the fluids which are employed in chemical operations as

solvents for other bodies, can be decided only by the same means.

The makers of oil of vitriol have no other way of knowing when the acid is in a proper state to be removed from the chambers of combustion; the calico-printer, who concentrates his own lemon-juice, has nothing else to direct his decision in determining whether the citric solution be fit for this or that particular style of work; nor does the modern bleacher, who is careful in his operations, ever dare to use the liquid hyperoxy-muriate of lime, till he has reduced it to that particular specific gravity at which he knows it may be used with safety.

Even the malleability, tenacity,

and hardness of some of the metals, and the volatilities of many fluid substances, may be ascertained or conjectured by an attention to their respective specific gravities; but to enumerate more individual instances would be useless, as I conceive the importance of the subject under consideration must now be fully apparent [10].

It has been before remarked, that specific gravity is only another name for comparative gravity, the absolute weight of the substance under exami-

[10] Those who wish to see more on the utility of the knowledge of specific gravity, may consult Boyle's Medicina Hydrostatica, or Cotes's Hydrostatical Lectures, 8vo, London 1775, page 82.

nation being always given in comparison with some other substance exactly of an equal bulk. In fixing this standard, water presented itself as the most convenient substance, and this, as I before stated, is now generally employed as the datum from which all calculations of specific gravity proceed, water being always called 1.000.

In estimating the specific gravity of fluids, it is usual to procure a large phial with a narrow neck, to fill this phial up to a certain part of the neck with some determinate number of even ounces, or any other known weight, of pure water, and then to mark the neck of the bottle with a diamond, precisely at the spot to

which the water ascends within it. The bottle being thus prepared, and the quantity of water which it holds up to the fixed mark being remembered, it is ready for use.

When any liquid substance is to be examined, all that is necessary is to pour into the bottle as much of the liquid under examination as shall exactly rise up to the mark on the neck, and then to weigh it accurately [11], and calculate the difference. For

[11] Some good remarks on the choice of an accurate pair of scales for philosophical purposes will be found in Mr. Nicholson's Chemical Dictionary, 8vo, 1808, article Balance. A very ingenious mode of making most minute and accurate weights is described by Dr. Lewis, in his Commerce of the Arts, p. 544.

instance, if it weigh exactly the same as an equal bulk of water, it is said to be of the specific gravity of water. But if the bottle hold four ounces of water, and the same measure of some other fluid should weigh *six*, it is evident that this fluid is half as heavy again as water, and water being 1.000, this fluid will be noted to be of the specific gravity of 1.500. The bottle usually employed by the soap-boiler, to ascertain the strength of his alkaline lyes, is of this kind.

Another method of ascertaining the specific gravity of fluids, is by noting the weight of some solid, such as a cube of glass, in distilled water, and then weighing the same substance in the liquid to be examined. These

weights should be noted in grains, and by dividing what the solid loses in the fluid by what it lost when it was weighed in the water, the quotient will be the real specific gravity of the liquid.

The specific gravity of fluids is also found by the areometer[12], a

[12] This instrument is of great antiquity. It was formerly supposed to have been invented at the close of the fourth century by Hypacia, the celebrated mathematician of Alexandria; but Usebe Salverte, in a memoir on this subject in the twenty-second volume of the Annales de Chimie, has shown that it was undoubtedly invented by Archimedes. This writer has given a Latin description of the instrument, from an author of great antiquity, and from this it appears that the ancient areometer was very similar in form to the modern.

mode that is attended with much less trouble than either of the former, but it is not likely in all cases to be equally accurate.

This instrument is a graduated glass tube, with a bulb at one end of it, and so contrived, by being balanced with mercury or lead, that it may swim in the fluid, in a perpendicular position [13]. The specific gravity is shown by the degree marked on the stem of the instrument, to

[13] Mr. Nicholson made a great improvement in this instrument, having adapted it to the measure of the density of solids as well as fluids. It is described in the second volume of the Manchester Memoirs, and a plate of it is given in the first volume of Mr. Nicholson's quarto Journal.

which it sinks in the fluid to be examined, and this will consequently always be lower in proportion as the liquid is lighter. The areometer of Baumé [14], which has long been the instrument in common use in France, is upon this construction.

In forming this instrument he had recourse to a process similar to that of graduating the stems of thermometers from two fixed points. The first of these points was obtained by immersing the instrument in pure

---

[14] The areometers of Baumé are very frequently mentioned in the writings of the French chemists: hence I deemed it adviseable to explain the principle on which they were founded.

water. At that point of the stem which was intersected by the surface of the fluid, he marked zero, or the first of his graduation, and this commenced at or near the upper extremity of the stem.

He then provided a number of solutions of pure, dry, common salt in water: these solutions contained respectively one, two, three, four, &c. parts of the salt, and in each solution the quantity of water was such as to make up the weight equal to one hundred parts in the whole; so that in the solution containing one part of salt, there were 99 parts of water; in the solution containing two parts of salt, there were 98 parts of water, and so on with the rest. The instru-

ment was then plunged in the first solution, in which of course it floated with a larger portion of the stem above the fluid, than when pure water was used. The fluid, by the intersection of its surface upon the stem, indicated the place for marking his first degree; the same operation repeated, with the fluid containing two pounds of salt, indicated the mark for the second degree; the solution of three pounds afforded the third degree; and in this manner his enumeration was carried as far as fifteen degrees. These first degrees applied with the compasses repeatedly along the stem, served to extend the graduation as far as was required. This instrument, which is

applicable to the admeasurement of densities exceeding that of pure water, is distinguished by the name of the areometer for salts [15].

[15] The instrument which is at present most in use by the philosophical chemists in France, is the Gravimeter of Guyton, which is said to be an improvement on Mr. Nicholson's. An ample description of it is given in Mr. Nicholson's quarto Journal, vol. i. page 110.

BAUMÉ's Areometer for Salts.

Temperature 55° Fahrenheit.

Deg.	Sp. Gr.	Deg.	Sp. Gr.
0	1.000	39	1.373
3	1.020	42	1.414
6	1.040	45	1.455
9	1.064	48	1.500
12	1.089	51	1.547
15	1.114	54	1.594
18	1.140	57	1.659
21	1.170	60	1.717
24	1.200	63	1.779
27	1.230	66	1.848
30	1.261	69	1.920
33	1.295	72	2.000
36	1.333		

His areometer for spirits is formed upon the same principle; but in this the counterpoise is so adjusted, that most part of the stem rises above the fluid when immersed in pure water: consequently the graduations to express inferior densities are continued upwards on the stem, instead of downwards as in the former instance.

Here a solution of ten parts by weight of salt, in ninety parts of water, affords the first point or zero; and the mark indicated by pure water is called the tenth degree; whence by equal divisions the remaining degrees are determined [16].

[16] For this account of the principle of Baumé's areometers, I am indebted to Mr. Nicholson's quarto Journal, vol. i. p. 37.

Baumé's Areometer for Spirits.

Temperature 55° Fahrenheit.

Deg.	Sp. Gr.	Deg.	Sp. Gr.
10 —	1.000	26 —	.892
11 —	.990	27 —	.886
12 —	.985	28 —	.880
13 —	.977	29 —	.874
14 —	.970	30 —	.867
15 —	.963	31 —	.861
16 —	.955	32 —	.856
17 —	.949	33 —	.852
18 —	.942	34 —	.847
19 —	.935	35 —	.842
20 —	.928	36 —	.837
21 —	.922	37 —	.832
22 —	.915	38 —	.827
23 —	.909	39 —	.822
24 —	.903	40 —	.817
25 —	.897		

In Great Britain and Ireland the specific gravity of ardent spirits is determined on another principle, and various instruments, called hydrometers, have been used for the purpose. Here, unfortunately, the specific gravity is not calculated from that of water, but from the strength of an arbitrary spirit, which the Excise Board calls proof spirit, the specific gravity of which is about 0.933. The relation which all other spirituous liquors have to the standard, is expressed by saying they are so much above or under hydrometer proof.

For instance, a spirituous liquor is said to be ten per cent. over hydrometer proof, when it is so strong that one hundred gallons of it will admit

an addition of ten gallons of water to reduce it to the strength of proof; and it is considered to be ten per cent. under proof, when one hundred gallons contain ten gallons of water more than is contained in proof spirits [17].

In chemical laboratories it would be inconvenient to depend solely on any instrument of the kind just described; for the range from the specific gravity of pure liquid ammonia to that of concentrated sulphuric acid is so great, that several different areometers would be required; it being almost impossible to construct a single one, on account of the great

[17] Speer on the Hydrometer, 8vo, London 1802, page 5.

length of its stem, that could be used with convenience for every purpose.

The following, however, and which is the mode that is now employed in Great Britain by all philosophical chemists, may also be adopted in the laboratory with advantage, as it is not liable to the same errors as the areometers [18] are, where the range is long, and this range is minutely divided.

All that is necessary is to provide a convenient glass bottle with a ground conical stopper [19], in the side

[18] Those who are attached to the use of areometers may be glad to be informed that the best are made in Scotland by Mr. Twaddle, and sold with a mahogany box, properly fitted up, to prevent injury by carriage.

[19] See plates, fig. 9.

of which stopper a fine mark is to be cut with a file. The weight of this bottle, with its stopper, should then be noted in grains, or a weight might be made that would always serve as a counterpoise. The bottle should then be filled with distilled water, and its weight accurately noted down in grains. When it is filled, it will be easy to put in the stopper, because the redundant fluid will escape through the notch[20] in the side of

[20] For this method of cutting a notch in the stopper of a gravity bottle, I am indebted to the ingenious Mr. Nicholson, who mentions it in his octavo Chemical Dictionary, under the article Hydrometer. Unless some such contrivance be adopted, it is difficult to fill a bottle without inclosing bubbles of atmospheric air with the fluid.

the stopper, and may be carefully wiped off.

Whenever the specific gravity of a fluid, heavier than water, is to be taken, the bottle should be filled with it, and its actual weight in grains written down: then, if this weight be divided by the weight of the water which the bottle is known to hold [21], the specific gravity of the fluid in question will be accurately ascertained.

Suppose, for example, I have to find the specific gravity of a solution

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[21] Where a bottle of this kind is not to be had, any phial may be used, if it be first ascertained what quantity of water such bottle is capable of holding.

of carbonate of potash, and that this bottle contains exactly 1750 grains of the solution, and that the same quantity of water weighs no more than 1425 grains. Here we have only to divide the greater by the less sum, and the quotient will be found to be 1,228; for although the decimal fraction may be extended, three places will be generally sufficient for all practical purposes; and in all cases we must make the weight of the contents in water the divisor, whether the fluid to be examined be lighter or heavier.

It must be recollected that the methods which I have already mentioned of taking specific gravities apply only to those of *fluids*: that of

solids is often attended with more difficulty.

It has been before remarked, that the specific gravity of bodies is in a direct ratio of their mass, and inversely as to their bulk. It is on the latter of these principles that the methods of taking the specific gravities of *solids* have been founded.

The usual method of taking the specific gravity of ores, metals, or other solid substances, is, by weighing them hydrostatically, that is, by comparing the difference which there is in their weights when weighed in air and in water[22], and to divide the

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[22] There is an inconvenience attending the weighing hydrostatically from the various tem-

absolute weight by the loss, the quotient being the specific gravity. Thus, if a mineral, which weighs three ounces in air, weighs only two ounces when immersed and weighed in

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perature of the water that may be used. To ensure accuracy, water of one known temperament ought always to be employed, as a variation in this respect will inevitably affect the result. An ingenious friend of mine recommends, that water should be drawn up from any *deep* well, believing that this will, in all climates, be uniformly of the same temperature, provided it be instantly employed: or, that a bottle filled with distilled water, and another vessel with the matter to be examined, may be lowered down, and kept in the same well till both have acquired the temperature of the subterraneous medium. This plan, he apprehends, will, on all occasions, be quite accurate.

water, the specific gravity of such mineral is 3; that is, if water, as it generally is, be called 1.000, the substance now examined is 3.000; or, to make it still plainer, if a pint measure of water weigh *one* pound, the same bulk of the mineral will weigh *three* pounds[23].

This method of weighing, and which can only be employed for solid bodies that are insoluble in water[24], is commonly conducted

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[23] There are some very minute directions for weighing a variety of substances hydrostatically in "Cotes's Hydrostatical and Pneumatical Lectures," page 57.

[24] When the specific gravity of a substance is required, which cannot be weighed in water, because it is soluble in that fluid, it may pro-

thus: The substance to be weighed is hung by a fine hair to one of the arms of a small scale-beam, which has a common scale-dish suspended to the other arm. When the article which is intended to be tried is suspended by the hair, it is accurately balanced by grain-weights, and the weight of it noted. It is then taken, still suspended to the arm of the balance, and immersed entirely in water[25],

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bably be weighed in some liquor that will not dissolve it. Thus, if it be a saline substance, it may probably be weighed with accuracy in a saturated solution of that salt.

[25] It is obvious that, in this method of taking specific gravities, water can be employed only for such substances as are above 1.000, or denser than water; because such bodies would not

which will destroy the equilibrium, and occasion the opposite scale to preponderate. Weights are then taken out of the scale till the balance is restored; and the amount of the weights which it is necessary to take out to restore the equilibrium, shows the difference there is in the weight of the substance when weighed in air and in water.

A more ready way to determine the specific gravity of solids, when circumstances will admit of it, is to

sink in the water, and it is necessary that they should be completely immersed. When it is required to weigh a body hydrostatically, that is specifically lighter than water, some heavier substance must be attached to it, and its weight also must be taken into account in making the calculation.

fill a phial with water, and note the weight of the whole accurately in grains. Then weigh 100 grains of the substance to be examined, and drop it gradually into the phial of water. The difference of weight of the bottle with its contents now, and when it was filled with water only, will give the specific gravity of the matter under consideration. For example, if the bottle weighs 50 grains more than it did when it was filled with water only, it shows that 100 grains of the mineral displace only 50 grains of water, and consequently that it is twice the specific gravity of water.

It was on this principle that Archimedes is said to have discovered

the deceit which had been practised upon his relative Hiero the Second, king of Syracuse, by an unprincipled goldsmith who had been employed to fabricate a crown of pure gold for him, as an offering to the gods.

The workman, it seems, had alloyed the crown with a portion of silver, imagining that the fraud could not be detected;—but Archimedes, suspecting that a cheat had been practised, hit upon the following method of ascertaining the fact:

He made two masses, each of equal weight with the crown, one of gold and the other of silver: when he had done this, he filled a large vessel to the brim with water, and put the silver

mass into it, upon which a quantity of water overflowed, equal to the bulk of the mass: then taking the metal out, he filled up the vessel again, measuring the water exactly which he put in: this showed him what measure of water answered to a certain quantity of silver.

He then tried the gold in like manner, and found that it caused a less quantity of water to overflow; the gold being less in bulk than the silver, though of the same weight. Having filled the vessel a third time, he then put in the crown itself, and found that it caused more water to overflow than the mass of gold of the same weight. From these data he calculated, as he imagined, how

much gold had been purloined, and what silver had been substituted in its stead [26].

This piece of history, which has been related a hundred times in various ways, would not have found a place here, but for the design of ingrafting upon it a very necessary and a very important caution.

It is natural for a person to conclude, when it had been once clearly ascertained that one of two metals, whose specific gravities differed, was the heaviest metal then known, that there would be no impediment in calculating how much of the lighter metal had been employed in forming an

[26] Vitruvius, lib. ix. cap. 3; and Biographical Dictionary, article "Archimedes."

alloy of the two metals: experience, however, proves the fallacy of such a theory.

Dr. Lewis, the first person who examined this subject with due care, made a great number of mixtures of the different metals; and the result of these experiments shows, "that the gravity of a metal can never be with any certainty deduced from that of its mixture with another metal, as a dilatation or contraction of the volume may result from their action on one another; and that when two metals of known gravities are melted together, their proportions cannot be found from the gravity of the compound, without a previous hydrostatic examination of known mix-

tures of them in different proportions [27]; and, consequently, that the celebrated proposition of Archimedes is of more limited use than has generally been supposed [28]."

In the mixture of crude platina with silver, it is well known that there is a diminution of specific gravity; and in its mixture with iron,

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[27] The apparent anomaly in the alloy of gold with silver, Dr. Lewis explains by stating, that the proportions of these metals should be calculated from their respective bulks, and not from their weights. A person who was acquainted with this fact, he says, made great profits in buying gold from the Chinese, who usually employ silver in their alloy of gold. Phil. Commerce of the Arts, page 125.

[28] Dr. Lewis's Philosophical Commerce of the Arts, 4to, London 1763, page 556.

an increase. Tin is specifically much lighter than copper, yet the specific gravity of the compound, bell-metal, is greater than that of copper itself[29]. From inattention to such facts many deceptions might arise, and innumerable errors be committed.

Mr. Scheffer made out a table for determining the quantities of lead and tin in any given mixtures of the two, by taking the specific gravity of the alloy; and this was published in the Swedish Acts for 1755. But as this table was formed without comparison with standard mixtures,

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[29] Dr. Lewis's Phil. Commerce of the Arts, page 555; and his Notes to Neumann, vol. i. page 97.

it cannot be depended upon, and is of no value.

The goodness of tin may be generally known by its specific gravity, though it would be erroneous to judge of the ores of tin by the same means, because some specimens of the best ores are of a specific gravity greater even than that of the pure metal itself[30].

A deception equally great would arise from an attempt to calculate the proportions of many of the mixtures of liquid substances, without having made previous experiments to determine the amount of their condensation by mixture: for, when two

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[30] Caspar Neumann, vol. i. page 131.

liquids unite chemically, the compound has generally a density greater than the mean density.

If we make a mixture of ardent spirit with water, the specific gravity of the mixture will not be a mean specific gravity. Water itself is of far greater gravity than the oxygen and hydrogen gas which compose it. One measure of sulphuric acid and one measure of water, when mixed, will not occupy the space of two measures; consequently the mixture cannot have a specific gravity corresponding to the mean between those of the two original fluids.

It will be remembered, therefore, that to ascertain the specific gravity of a body may serve to furnish some

idea of its purity, some substances being increased, and others diminished, in their specific gravities, by sophistication; that it will indicate the comparative value of certain metallic, acidulous or alkaline solutions, and has innumerable other uses in the hands of the manufacturing or philosophical chemist, some of which have been mentioned at page 11—14: it does not, however, afford any means of accurately discovering the amount of adulteration, or establishing a proof of the quantities of the components, whether the mixture be fluid or solid.

Nothing now remains but to notice a distinct method of taking the specific gravity of fluids, which dif-

fers in some respects from those already described, and is that which I have adopted in my own business for many years past.

This ingenious contrivance, which originated with Dr. Lewis, was communicated to me by the amiable Mr. Samuel Moore, late Secretary to the Society for the Promotion of Arts, Manufactures and Commerce, who favoured me with a sight of Dr. Lewis's manuscript, and allowed me to make such extracts from it as I conceived might be useful.

In this scheme the specific gravity of a liquor is estimated from the excess of the weight of a certain measure of it, above that of an equal measure of distilled water. For this

purpose, a peculiar set of weights, which he called CARATS, is to be made in the following manner:—

A convenient bottle, with a long narrow neck[31], being procured, the tare of the bottle is first taken, and a weight made corresponding thereto, as the exact counterpoise: it is then to be completely filled with distilled water, or till the water rise to a mark made in such part of the neck as shall be found most convenient. A weight corresponding to the net weight of this water is then to be made, and marked 128; after which this weight is to be accurately divided into two equal parts, and a

[31] See plates, fig. 10.

weight made equal to one of these parts is to be marked 64. By continuing the subdivision we shall have the weights 32, 16, 8, 4, 2, 1, carats; so that each carat, though in some measure of an arbitrary value, must be $\frac{1}{128}$ of the water required to fill such bottle.

When these weights are adjusted, it will be proper to make another counterpoise besides that already described for the tare of the bottle, and this must be an exact balance to both the water and bottle. We then make our estimate in this way: So many carats as the bottle when filled with any other fluid, exceeds this united weight or *counterpoise*, so many

carats strong is such fluid to be estimated.

This apparatus is equally useful for taking the specific gravities of alcohol, ether, liquid ammonia, oils, or any other fluid body which is lighter than water. In such cases, the only variation necessary is to put the carat-weights in the scale with the bottle, instead of putting them with the water-poise; and whatever number of carats may be required for bringing the bottle and the water-poise to an equilibrium, so many carats is the fluid lighter than an equal measure of pure water; and as the perfection of these liquids is in a direct ratio with their levity, their true value is at once demonstrated.

Carats.	Sp. Gr.	Carats.	Sp. Gr.
63 =	1.4921	84 =	1.6562
64	1.5000	85	1.6640
65	1.5078	86	1.6718
66	1.5156	87	1.6796
67	1.5234	88	1.6875
68	1.5312	89	1.6953
69	1.5390	90	1.7031
70	1.5468	91	1.7109
71	1.5546	92	1.7187
72	1.5625	93	1.7265
73	1.5703	94	1.7343
74	1.5781	95	1.7421
75	1.5859	96	1.7500
76	1.5937	97	1.7578
77	1.6015	98	1.7656
78	1.6093	99	1.7734
79	1.6171	100	1.7821
80	1.6250	101	1.7890
81	1.6328	102	1.7968
82	1.6406	103	1.8046
83	1.6484	104	1.8124

Carats.	Sp. Gr.	Carats.	Sp. Gr.
105	1.8202	117	1.9140
106	1.8280	118	1.9218
107	1.8358	119	1.9296
108	1.8436	120	1.9375
109	1.8514	121	1.9453
110	1.8593	122	1.9531
111	1.8671	123	1.9609
112	1.8750	124	1.9687
113	1.8828	125	1.9765
114	1.8906	126	1.9843
115	1.8984	127	1.9921
116	1.9062	128	2.0000

For those persons who have been in the habit of calculating specific gravities by the wine-pint, or, to speak more accurately, by a measure holding exactly sixteen avoirdupois ounces of water[32], as also for those who may not be conversant with the mode of reckoning specific gravities by decimal arithmetic, I subjoin the following table.

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[32] It has been decided that the wine pint holds rather more than sixteen ounces of water; but it is most convenient for all common purposes, still to consider it as a measure of sixteen ounces, and this table is constructed accordingly.

A Table of Carats, with their correspondent Weights of the Wine Pint, in Ounces and Drachms Avoirdupois.

Carats.	Oz.	Dms.	Carats.	Oz.	Dms.
1 =	16	2	20 =	18	8
2	16	4	21	18	10
3	16	6	22	18	12
4	16	8	23	18	14
5	16	10	24	19	0
6	16	12	25	19	2
7	16	14	26	19	4
8	17	0	27	19	6
9	17	2	28	19	8
10	17	4	29	19	10
11	17	6	30	19	12
12	17	8	31	19	14
13	17	10	32	20	0
14	17	12	33	20	2
15	17	14	34	20	4
16	18	0	35	20	6
17	18	2	36	20	8
18	18	4	37	20	10
19	18	6	38	20	12

Carats.	Oz.	Dms.	Carats.	Oz.	Dms.
39 =	20	14	61 =	23	10
40	21	0	62	23	12
41	21	2	63	23	14
42	21	4	64	24	0
43	21	6	65	24	2
44	21	8	66	24	4
45	21	10	67	24	6
46	21	12	68	24	8
47	21	14	69	24	10
48	22	0	70	24	12
49	22	2	71	24	14
50	22	4	72	25	0
51	22	6	73	25	2
52	22	8	74	25	4
53	22	10	75	25	6
54	22	12	76	25	8
55	22	14	77	25	10
56	23	0	78	25	12
57	23	2	79	25	14
58	23	4	80	26	0
59	23	6	81	26	2
60	23	8	82	26	4

Carats.	Oz.	Dms.	Carats.	Oz.	Dms.
83 =	26	6	106 =	29	4
84	26	8	107	29	6
85	26	10	108	29	8
86	26	12	109	29	10
87	26	14	110	29	12
88	27	0	111	29	14
89	27	2	112	30	0
90	27	4	113	30	2
91	27	6	114	30	4
92	27	8	115	30	6
93	27	10	116	30	8
94	27	12	117	30	10
95	27	14	118	30	12
96	28	0	119	30	14
97	28	2	120	31	0
98	28	4	121	31	2
99	28	6	122	31	4
100	28	8	123	31	6
101	28	10	124	31	8
102	28	12	125	31	10
103	28	14	126	31	12
104	29	0	127	31	14
105	29	2	128	32	0

Before I close this Essay, I must inculcate the necessity of attending to the degree of temperature of the atmosphere when the experiment is made, as well as to that of the material to be examined, when its temperature is raised, or diminished, so as to deviate from the former; for we know that the specific gravity of all bodies is greatly influenced by sensible caloric, and their bulk increased or diminished in proportion to the quantity they contain.

Mr. Nicholson has stated, that he finds by experiment that the fifth decimal figure changes in *water* at every three degrees of Fahrenheit's thermometer. Other fluids will undoubtedly observe a different ratio; but a ma-

nufacturer, to whom it is often necessary to try the specific gravity of one particular liquor, might, for his own use, easily form a table of these variations.

ESSAY IV.

ON

CALICO PRINTING.

ESSAY IV.

on

CALICO PRINTING.

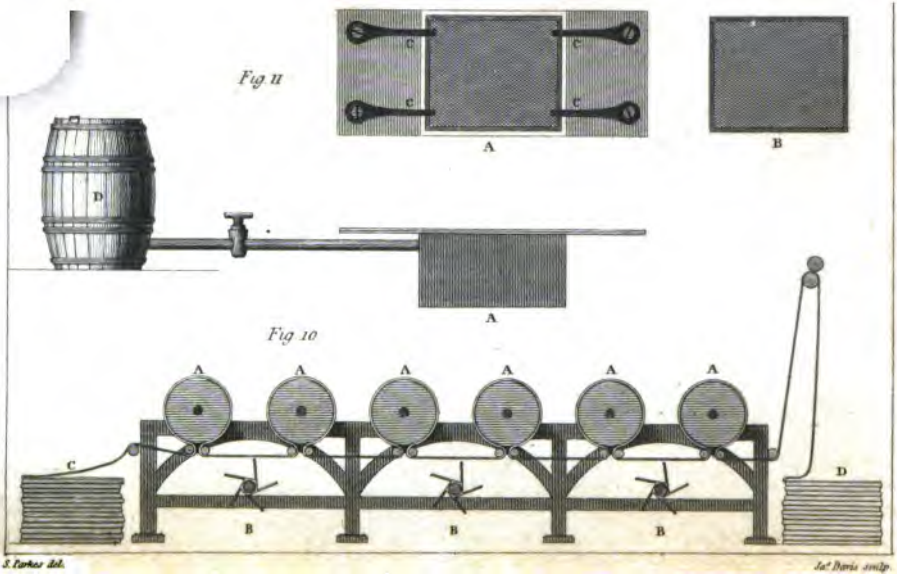
Fig 11
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Fig 10
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S. Parkes del.
Jas. Davis sculp.

ESSAY IV.

ON

CALICO-PRINTING.

CALICO-PRINTING is an art of very considerable importance to this country; it has proved the source of immense wealth to many individuals, and for several years past has brought a great revenue to the state. Notwithstanding its value and national consequence, the majority even of well-informed people, know little or nothing of the processes by which this peculiar manufacture is conducted.

This ignorance will appear the more remarkable, when it is considered that linens were fabricated, and the arts of dyeing and staining garments, something like the present calico-printing, were known and practised in the earliest ages of which history gives us any detail.

Hence it might very fairly be presumed that a faithful account of the nature of this business would be very acceptable to the public, and that, in the course of the narration, if any improvements on the present practice should be suggested, it is possible that such an account may not, even to the calico-printer himself, be totally uninteresting and useless. We shall begin with an attempt to trace

the history of the art, and of its progress towards that perfection to which it has now attained.

In the time of Moses the land was employed for the growth of flax[1]; and that this flax was used for the fabrication of cloth, may be collected from a variety of circumstances, especially from the account of an examination of some Egyptian mummies, the most ancient of which, at least such as have been brought to Europe, are bound round with folds of linen[2],

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[1] Exodus ix. 31.

[2] There is a paper of Dr. Hadley, in the fifty-fourth volume of the Philosophical Transactions, giving an account of the examination of an Egyptian mummy, in the presence of several of the Fellows of the Royal Soci-

similar to the flaxen cloth of the present day[3].

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ety. After describing its general appearance, he says, "The outward painted covering being removed, nothing but linen fillets were to be seen, which enclosed the whole mummy. The uppermost fillets were of a degree of fineness nearly equal to what is now sold in the shops under the name of long lawn, and were woven something after the manner of Russian sheeting." This mummy, it is understood, was taken from a catacomb near Cairo; and when the age of these catacombs is considered, it gives great antiquity to the art of weaving fine linen.

[3] That the invention of weaving is still more ancient than even the embalming of the mummies, is evident from the answer which Abram gave to the King of Sodom:—"I will not," said he, "take from a thread of the woof, even to a shoe-latchet, lest thou

Moses informs us that Abimelech made a present of a veil to Sarah[4]. He observes also, that Rebecca covered herself with a veil, when she perceived Isaac[5]; and that Pharaoh arrayed Joseph in a vesture of fine linen or cotton, when he made him viceroy of Egypt[6]. A weaver's shuttle is mentioned in the book of Job[7]. These facts prove the great antiquity of the art of weaving with warp and woof.

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shouldest say, I have made Abram rich." Genesis xiv. 23.

[4] Genesis xx. 16. [5] Ibid. xxiv. 65.

[6] "And Pharaoh took off his ring from his hand, and put it upon Joseph's hand, and arrayed him in vestures of fine linen." Genesis xli. 42.

[7] Job vii. 6.

In these very ancient times this work was performed in a standing posture [8]. Both Homer [9] and Virgil [10] attest this. This was owing to the construction of their looms, in which the warp was extended perpendicularly from top to bottom, and kept firm by means of a piece of wood, to which they hung very heavy weights [11].

"Inventress of the woof, fair Lina flings
The flying shuttle through the dancing strings,
Inlays the broider'd weft with flowery dyes,
Quick beat the reeds, the pedals fall and rise;

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[8] Junius de Pictura Veter. lib. i. cap. 4. p. 26.

[9] Lib. i. ver. 31. [10] Georgic. l. i. v. 294.

[11] Goguet's Origin of Laws, &c. vol. i. 126.

Slow from the beam the lengths of warp unwind,
And dance and nod the massy weights behind [12]."

Five hundred years after the death of Moses, and nearly a thousand years before Christ, it is related that Solomon imported linen yarn from Egypt [13]: and after this period the city of Tyre is represented as abounding in fine linen; for, when Ezekiel is describing the grandeur of that city, and the opulence of her merchants, he says: "They have made

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[12] Botanic Garden, part ii. cant. ii. l. 67.

[13] "And Solomon had horses and linen yarn brought out of Egypt; the king's merchants received the linen yarn at a price." 1 Kings x. 28.

all thy ship-boards of fir trees, of Senir; they have taken cedars from Lebanon to make masts for thee; FINE LINEN [14] with broidered work from Egypt, was that which thou spreadest forth to be thy sail [15]."

Hence we have reason to conclude, that linen cloth has been in use, though perhaps not very commonly, from the time of Moses to the present day.

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[14] From the manner in which this is mentioned, it is evident that the writer considered fine linen to be an article of great rarity. In his days *matting* was commonly used for sails; hence sails of *linen* must have been thought extremely magnificent. Sails of matting are still used on the vessels navigated by the Arabs on the Red Sea. Harmer.

[15] Ezekiel xxvii. 7.

We have the positive evidence of Pliny, that in his time there were many ancient families at Rome, who boasted of never having admitted linen cloth into their houses, considering the use of it as a mark of great and criminal effeminacy [16].

Some of the Roman emperors, however, were so desirous of having their subjects instructed in the manufactory of it, that they formed colleges in various parts of their home and foreign dominions, for teaching the art of weaving linen cloth; and one of these imperial manufactories was established at *Venta Belgarum*,

[16] Plin. Hist. Nat. lib. ix. c. 1.

the site of the present city of Winchester [17].

Equally decisive is the testimony of history respecting the antiquity of *coloured* linens, which appear to have been known almost in the very earliest ages.

More than three thousand years ago, a shrewd matron tied a *scarlet* thread round the hand of one of Tamar's children [18]; and Homer, who flourished nine hundred years before Christ, speaks of the variegated cloths of Sidon as very magnificent productions [19]. Jacob made for

[17] Cambden's Britan. vol. i. p. 139.

[18] Genesis xxxviii. 27.

[19] Iliad. lib. vi. line 289.

Joseph a coat of many colours, which was probably of linen, or of cotton [20]; and some hundred years afterwards we read of Solomon sending to Tyre for coloured linens, and of the king of that country answering his request, by furnishing him with "a man skilful to work in gold and in silver; in brass, in iron, in stone, and in timber; in purple, in blue, in *fine linen*, and in crimson [21]."

The Pentateuch frequently mentions the ornaments for the Tabernacle, as composed of blue and purple and scarlet and fine linen; and it has been remarked by Mr.

[20] Genesis xxxvii. 3.

[21] 2 Chronicles ii. 14.

Delaval[22], that in those books these colours are constantly arranged exactly in the same order[23], and that this order is the true prismatic series of those colours.

This is certainly a very striking fact; and it is also not a little curious, that after a lapse of several centuries which intervened between the period described in Exodus and the time of

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[22] See Delaval's "Experimental Inquiry into the Cause of the Change of Colours in opake and coloured Bodies." To this work I acknowledge myself indebted for many hints of which I have availed myself in the course of this Essay.

[23] See Exodus xxv. 4. xxvi. 1. 31. 36. xxvii. 16. xxviii. 6. 8. 15. xxxv. 6. 23. 25. 35. xxxvi. 8. 35. 37. xxxviii. 23. xxxix. 1—29. and several other places.

Solomon, the colours employed in the Temple ornaments should be still mentioned in the same order as those of the Tabernacle had been formerly noticed [24]; which is exactly the case, excepting one single alteration, viz. that of calling the red crimson instead of scarlet [25].

An historian who wrote more than four hundred years before the commencement of the Christian æra,

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[24] May not this be considered as an internal proof of the antiquity of the sacred writings? We know how much mankind have at all times been addicted to copy Nature; and next to the great luminary of our system, the rainbow was surely the grandest object which the writers of these books had ever beheld.

[25] 2 Chronicles iii. 14.

when describing the nations which inhabited Caucasus, a mountain extending throughout the region of Georgia and Armenia, affirms that by means of vegetables ground and diluted with water, they adorned their cloth with the figures of various animals, and that the dyes were permanent which were thus obtained [26].

Valerius Flaccus, an historian who

[26] "Le Caucase est habité par plusieurs nations différentes.

"On assure que ces peuples ont chez eux une sorte d'arbres dont les feuilles broyées et mêlées avec de l'eau fournissent une couleur avec laquelle ils peignent sur leurs habits des figures d'animaux. L'eau n'efface pas ces figures—et, comme si elles avaient été tissues, elles ne s'usent qu'avec l'étoffe." Larcher's translation of Herodotus, i. 203.

wrote in the age immediately succeeding that of Christ, "distinguishes a warrior slain at Colchis, during the Argonautic expedition, by a *painted* garment [27], and at the same time specifies that his dress was of fine white linen [28].

That dyeing materials were, in ancient times, plentifully produced at Colchis and Tournefort, is well known; and according to Mr. Delaval, great quantities of these mate-

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[27] "Cadit .....Tautantis alumnus ...
Tenuia non illum candentis carbasa lini,
Non auro depicta chlamys, non flava galeri
Cæsaries, pictoque juvant subtemine braccæ."
VALERIUS FLACCUS, vi. 221 et seq.

[28] Pliny says, that in his time the finest cloth was made from the cotton plant, which grew in India and in Persia. Lib. xii. cap. 10.

rials are still used in the very same species of dyeing. Besides, more than two thousand camel loads of madder are annually sent from Georgia to Diurbeck and India, where the finest calicoes are still painted with it[29].

Strabo, the celebrated Greek philosopher, who was contemporary with our Saviour, relates that the Indians wore flowered linens[30], and that India abounded with drugs, roots, and colouring substances[31], from

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[29] Delaval, page xxi.

[30] Strabo, lib. xv. p. 709.

[31] The inhabitants of India used a purple and scarlet dye, resembling cochineal in colour, and in the manner of its production. Delaval.

which some very beautiful dyes were produced[32].

The statues of Isis, which formerly were so abundant in Egypt, were adorned with *parti-coloured* cloths, which, as has been remarked, must have been of linen, or of cotton[33], because woollen was so much abhorred by them, that the lowest of the people would neither use it[34] nor allow it to be employed even in their interments. Such indeed was their

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[32] Strabo, lib. xv. p. 694—699 de India.

[33] Delaval, page 34.

[34] "And it shall come to pass, that when they enter in at the gates of the inner court, they shall be clothed with linen garments, and no wool shall come upon them." Ezekiel xliv. 17.

aversion, that it extended to the flocks, and to the very shepherds[35] themselves who attended them.

The methods which the Egyptians adopted to produce these parti-coloured linens is very particularly described by the Elder Pliny, who perished by an eruption of Vesuvius in the year 79 of the Christan æra. "The Egyptians," he says, "began by painting, or drawing, on white cloths with certain drugs, which in themselves possessed no colour, but had the property of attracting or absorbing colouring matters. After which, these cloths were immersed in a heated dyeing liquor; and though

[35] "Every shepherd is an abomination unto the Egyptians." Genesis xlvi. 34.

they were colourless before, and though this dyeing liquor was of one equable and uniform colour, yet when taken out of it soon afterwards they were found to be wonderfully tinged of different colours, according to the peculiar natures of the several drugs which had been applied to their respective parts; and that these colours could not be afterwards discharged by washing[36]."

The agreement which there is between this account of the management of the ancients and the present practice, cannot fail to strike any one who is in any way conversant

[36] See Pliny, lib. xxxv. cap. 11. § 42; and Bancroft on Permanent Colours, vol. i. p. 170, Goguet's Origin of Laws, vol. i. page 105.

with the processes now in use. And from this relation, and other testimony on record, there can be no doubt but that they employed both iron and alum as mordants, though these mordants might not be prepared exactly in the same way as they are used by the moderns.

Native soda, which abounded in Egypt, was also known to the ancients; and we have the direct assurance of Pliny that the dyers of antiquity were in the habit of using it in their processes [37].

But amongst the countries of the East which practised dyeing, the

[37] Lib. xxxi. cap. 10. Potash is the article generally employed by the English, though some use soda.

Phœnicians were the most celebrated, and particularly for their purple colour. So great was the demand for this article, that the city of Tyre grew to a vast extent, from the number of workmen employed in its manufacture [38].

It is also well known, that the Phœnicians resorted to Britain [39]

[38] Strabo, lib. xvi. page 757. It was from a sense of the great national utility of their purple dye, that the Phœnicians attributed its invention, which was the principal foundation of their trade and wealth, to the gods. Delaval.

[39] "The Phœnicians (says Campbell) were the first who moulded commerce into a science, and framed to themselves the glorious design of making mankind known and useful to each other. They knew that all countries were rich by nature, or might be made so by industry and art;

at a very early period of history[40]; can there then be any doubt but that the tin which they brought from this island[41] was used by them in dye-

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and therefore they did not only visit remote regions for what they could bring away, or obtain from the barbarous inhabitants for gewgaws and trifles, but they endeavoured to propagate sense, civility, and the art of living; and, in short, wherever they came, sought to make the people as wise and as industrious as themselves." Campbell's Political Survey of Great Britain, vol. i, page 24.

[40] "The first nation which visited this island on account of trade, was unquestionably the Phœnicians. This is positively affirmed by Strabo, and acknowledged by many other authors." Henry's History of Great Britain, 8vo, vol. ii, page 199.

[41] That tin was very early an object of merchandize with the Phœnicians, we have the

ing? for we know that this metal is absolutely necessary to the production of some certain red colours, whether the materials from which the colouring matter is produced be of animal or vegetable origin[42]. Indeed, according to Pliny, the vats themselves in which the Tyrian dye was made, were of tin[43], the very best possible material for the purpose, and

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positive testimony of a writer who flourished 600 years before Christ. In describing the riches and consequence of Tyre, one of the chief cities of Phœnicia, he says, "With silver, iron, TIN, and lead, they traded in thy fairs." Ezekiel xxvii. 12.

[42] Delaval, page 50.

[43] Plini, lib. ix. cap. 38.

what the opulent dyers in this country now employ[44].

Besides the purple which was thus prepared at Tyre and other parts of Syria, the ancient inhabitants of India were also in the habit of using a purple and scarlet dye, which they procured from the cochineal insect, or from some other insect resembling it. For Ctesias the physician, who flourished about four hundred years

[44] The majority of the English dyeing-vessels are of copper; but those who are curious in their colours, particularly the large woollen dyers, invariably have them of tin. Some of these pans weigh more than two tons, and cost from 400*l.* to 500*l.* each.

Mr. Boyle, 130 years ago, discovered that

before Christ, and was a great favourite at the court of Persia [45], and after hi Ælian the philosopher, who taught rhetoric at Rome in the reign of Alexander Severus, give an account of the insects which yielded it, and of the plants on which they

a bright scarlet was never produced unless *tin* vessels were employed. Experimenta de Coloribus, 4to, 1680.

[45] There can be little doubt but that the true cochineal was known in Persia very early. The king of Persia, we are told, sent to the emperor Aurelian, among other things of value, some woollen cloth which was of a much brighter purple than any that had ever been seen in the Roman empire, and in comparison of which all the other purple cloth worn by the emperor and the ladies of the court appeared dull and faded. Beckman, from Vopiscus in Vita Aureliani, cap. 29.

fed. We also learn that so large a quantity of this colouring matter was produced in India, as to become an article of export in those early times. From this insect, whatever it might be, it is probable that these Asiatics were supplied with that abundance of purple, which enabled even the lowest ranks among them to wear clothes of that colour[46].

From various accounts it appears, that formerly, in India, the cotton cloths, when brought from the weavers, partly bleached, were worn next to the skin, by the dyer and by all his family, during the space of eight or ten days[47], after which they un-

[46] See Delaval's preface, page 24.

[47] These cottons could not have been of a

derwent several macerations in water, with goats' dung, and were afterwards submitted to frequent washings, and to as frequent dryings in the rays of an intense sunshine. Afterwards, they were soaked for some time in the mixture of the astringent fruit of the yellow *myrobalans*, and of curdled buffalo's milk. When thoroughly impregnated therewith,

length equal to the pieces of the present day; they were probably nothing but mere shawls, for these have been common in India for time immemorial. Among the magnificent dresses of the present Asiatics, there is nothing more esteemed than shawls of various colours, and these are frequently given to the great by way of present. Irwin's Travels up the Red Sea, pages 60. 189. 272. 285. Dr. Clarke's Harmer, vol. iv. 256.

they were squeezed, dried by exposure to the sun, and then, by pressure and friction, they were made smooth enough for being drawn upon by the pencil, with the different mordants.

The first of these mordants was an iron liquor, made by dissolving iron in a mixture of sour palm wine, and of water in which rice had been boiled. This liquor was applied to the figures or spots intended to become black, and afterwards the aluminous mordant was applied, commonly by children, with the pencil, to the parts intended to be made red. The pieces were then exposed to the hottest sunshine, that the parts to which the mordants had been applied might be dried as much as possible;

and then they were thoroughly soaked in pits of water, to cleanse them from the superfluous mordants, as well as from the buffalo's milk, &c.; and lastly they were dyed in water, with certain roots answering nearly in their effects to those of madder [48].

It was in this way the manufacture of printed cottons was conducted by the Indians in *former* times. The following is an account of the *modern* practice, in one particular branch of their manufacture, which I procured from a gentleman who

[48] Most of these particulars were published by Father Cœurdoux, a missionary at Pondicherry, in the twenty-sixth volume of "Recueil des Lettres Curieuses et Edifiantes, &c." See Bancroft on Permanent Colours, p. 172.

has spent some time in India, and which I now subjoin, rather for the amusement than the instruction of the British calico-printer.

The finest cotton chintz counterpanes, says he, which the natives call pallampoors, are manufactured at Madras. These are woven in one piece, from two to four yards square, and are printed, or rather painted, with various designs, and in various colours. Their method is to draw the pattern first on sheets of paper sewn together, of the size of the intended pallampoor; and then to prick out the same in the paper with a sharp instrument. This done, the paper pattern is smoothly fixed upon the cloth, which is previously damp-

ed, and a small muslin bag containing some kind of black powder is rubbed over the whole, in order to pass a part of the powder through the pin holes, and completely mark out the pattern.

The pattern being thus sketched upon the cloth, the paper is removed; and when the outline of the various figures is drawn with a pencil, the piece is considered to be ready for receiving the colours.

One colour is then laid on with a brush[49] made with a tough root

[49] As all the colours on Indian calicoes are imparted by the pencil, it appears to me that whenever the trade to the East is thrown open, a fine opportunity will be afforded of selling immense quantities of British printed

of a particular kind of tree, or with the husk of the cocoa nut; and when this is dry, the piece of cotton is given to a woman to wear, or to use in the family, till it be very much dirtied; in order that it might necessarily undergo a thorough washing, which

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goods; for though this is an article of manufacture which the Company has not been able to introduce, on account of the attachment of the natives to their own peculiar style of work, yet the case may be altered when some spirited individuals shall undertake to copy the Indian patterns, and introduce such imitations as the product of India. The difference there would be in price, is at present incalculable; for patterns which would require several weeks to finish a piece with in India, might, by means of the cylinder, be done here in a few minutes.

is thought requisite to prove the goodness and permanency of the colour. Another colour is then laid on in the same manner, and the piece is again submitted to the same trial of wearing and washing [50]. This is repeated for every colour that is employed;—and when any one of these colours is found to be deteriorated by this treatment, it is printed afresh; and so are all the rest, till the workman is satisfied that all the colours are actually permanent.

[50] The Asiatics may not be aware of it; but doubtless the long exposure to the air in these cases, is the important point, as it is well known that the atmosphere is a prime agent in rendering many colours permanent, which, under a different treatment, would be heavy and fugitive.

This tedious process is adopted, however, only when the manufacturer means to warrant the article; but in all cases, even in those pieces which will not bear washing, the colours are laid on by a brush, as before mentioned.

Whether they are all substantive colours which are thus applied, or whether they use any species of mordants in their fast work, I am unacquainted, as my friend had no information on this subject.

Such are the facts which I have been able to collect respecting the progress of calico-printing from the earliest ages; and also of the present state of the art among the Asiatics. The more difficult part now remains,

viz. to give a brief detail of the most important processes of our own artists. This, however, I shall endeavour to do with the utmost plainness, and shall not fail to suggest any improvement that may ever have occurred to me during my inquiries respecting this very interesting and varied branch of manufacture.

But here it may be necessary to remark, that although I am at full liberty to relate the common outlines of the business, and to suggest such improvements as may have occurred to myself, still there are sundry new ideas and discoveries which have been communicated to me in confidence by some very ingenious men, which I should not be justified in revealing.

And, as the business of a manufacturing chemist occasions me to have a continued intercourse with most of the principals in these manufactories, through a long line of country from Aberdeen to the metropolis, I am glad of the opportunity of saying thus much, feeling that the utmost delicacy must always be observed in this respect, by every man who is at all desirous of not forfeiting the confidence of the wise and respectable part of the community.

I have not yet been able to ascertain when calico-printing was introduced into this country, though there are various reasons for believing that it is an art, among us at least, but of modern date.

As the whole of this ingenious business, as it is now conducted, depends upon the proper application of a few compounds called mordants, it will be necessary, in the first place, to explain their nature and uses. In doing this, one or two preliminary remarks will assist us.

The colouring substances chiefly employed in this art, are divided into two classes, viz. *substantive* and *adjective*. A SUBSTANTIVE colour is one which is capable of itself of producing a permanent dye on wool or woollen cloth; such is the juice of the buccinum [51], used by the ancients

[51] It has been proposed to employ this valuable permanent colour for penciling on fine

for producing the imperial purple; such are also the woad and indigo [52] employed by the moderns for producing a permanent blue; and we may add the metallic solutions, particularly those of iron, cobalt, gold, platina, and silver, which give various colours, according to the processes by which they are prepared.

By ADJECTIVE colours is meant all those which are incapable of giving

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muslins. In time of peace it might readily be procured in sufficient quantities, and would prove an important addition to the resources of the British calico-printer.

[52] Dr. Bancroft tells us, that the first mention of indigo, as known in England, is in the Act of the 23d of Queen Elizabeth, chap. 9. where it is called *Ancle*, or *Blue Inde*. Bancroft on Permanent Colours, page 138.

permanent dyes without the aid of certain intermedia, which form as it were a bond of union between them and the substances intended to be dyed.

These intermedia are what are known by the term MORDANTS, and are used for this purpose in very considerable quantities by the calico-printer of the present day.

Several expedients of this kind were employed by the ancients to produce fast, or, more properly, permanent colours, and this appears from the testimony of Aristotle and Pliny. The chief articles in use at present, are the acetate of iron, the acetate of alumine, and the various solutions of tin, all of which should

be very carefully and correctly prepared.

When piece-goods are designed to be dyed of one uniform adjective colour, they are first immersed in a solution of one of these mordants, then hung up to dry, and to absorb the oxygen of the atmosphere. When sufficiently exposed to the air, they are washed or dunged [53], to remove the superfluous mordant; that is to

[53] The dung of the cow is used in such large quantities by the calico-printer, that it has become an article of great expense. The proportion that is employed is usually about one bushel to one hundred gallons of water, though frequently a larger proportion would be more effectual. The brightness of the colours, and the purity of the whites, are always dependent upon the quantity of the dung employed.

say, that part of it which is not chemically combined with the cloth; and the goods are then submitted to a bath of that particular kind of colouring matter which is to be imparted to them.

Whenever it is meant that the colour should be partially inserted, the mordant is applied to those particular parts only; so that, when the piece is immersed in the colouring bath, no other place will receive the permanent stain [54]. For though the

[54] If a sufficient number of colouring substances should ever be discovered, that have no affinity for anything but the chemical mordants, the business of calico-printing would be rendered much more easy and simple than it is at present.

whole texture of the cloth will be coloured, yet having in itself no affinity with the vegetable with which the decoction is impregnated, the whole of the colouring matter will be easily removed by exposure to the air, and the ground of the piece restored to its original whiteness; while those parts to which the mordant was applied, will retain and fix the colours in a way which will be more fully explained hereafter.

Formerly all calico-printers were bleachers; but in the neighbourhood of London these are separate and distinct trades, and the printer either purchases bleached goods for printing on his own private account, or receives the cloth from his customers

in a white state; and, when printed, he returns the identical pieces, and is paid so much per yard, according to the number of colours, for printing them.

In my opinion every printer should bleach his own goods [55], for it is

[55] Oxymuriate of lime is the agent generally employed in bleaching; but it appears to me that some other article might be introduced with advantage. For, as the goods are washed in diluted sulphuric acid when they are taken from the oxymuriate of lime, a sulphate of lime is always formed, which becomes fixed in the fabric, and, acting as a mordant when the pieces come into the madder copper, occasions an indelible stain, which in very fine goods often impairs their beauty. If oxymuriate of soda were employed, the sulphuric acid would form a soluble salt with the soda, easily removable by washing.

impossible always to rely with confidence on the care of those who bleach for hire; and every printer knows that good bleaching is absolutely a necessary preliminary in the production of good printing. Indeed, this is now pretty generally acknowledged in the North of England; for most of the opulent houses in Lancashire and in Scotland, who produce fine work, are bleachers as well as printers.

No people have taken more pains to excel in bleaching than the Irish, and their credit is established accordingly. The German linen is, I believe, generally better than theirs; but the Irish has always the preference in foreign markets, owing to

their superiority in bleaching and finishing.

By whatever means the bleaching is performed, the printer commences his part of the business in the following manner.

The goods are first DRESSED by singeing off the whole of the nap which is attached to them. This is effected by the following contrivance: Ten pieces are generally wired together, and wound upon a roller, from whence they are passed over a hot iron, nearly in the form of half a cylinder, and received upon another roller; from thence they are returned to the iron, which is still kept red or nearly at a white heat. The use of repeating this process is to remove the

nap more effectually than it would be done by passing it only once over.

The next operatoin is that of STEEPING, which consists merely in soaking the pieces for 24 hours in a vessel of weak alkaline lye, at a temperature of about 100°. These operations of singeing and steeping are going on at one and the same time, which effectually prevent any accident that might otherwise arise from the effects of the hot iron.

The goods are then boiled or else bowked in a solution of potash, (some workmen prefer to have this alkali in a pure caustic state [56],) they

[56] By some observant calico-printers it has been imagined, that the rendering the lye

are then well cleansed, by thorough washing in wash-wheels, or in stocks, to insure their being entirely divested of the alkali. The intention of thus treating them with potash, is to remove any grease or impurity that may be attached to them, which would otherwise endanger the evenness and uniformity of the colours. This process is called ASHING.

It may be remarked, that in weaving calicoes the workman generally greases the reeds [57], in order to make

caustic is apt to impair the texture of the cloth; and I doubt not but that this has often been the case. Under the eye of the master, however, I am sure it might be employed with advantage and safety.

[57] Tallow is also employed for dressing the

them move easier. Wherever this grease is in the cloth, it becomes fixed by the operation of singeing; and if it be not taken out before bleaching, it will not come out afterwards by the usual process of ashing and souring; for, when the pieces are submitted to a blue vat to be dyed of a uniform self-colour, all those greasy places will be found to have taken the dye in a very imperfect manner[58].

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warp, and this has a baneful effect on all goods which are designed for printing.

[58] If the calico-manufacturers themselves would make a point of preparing the oleaginous matter for the weavers, and would furnish them with nothing but pure VEGETABLE OILS, such as those of rape, linseed, &c., I think it very likely that these inconveniences would not occur; for the stain from *vege-*

To cleanse such goods, various expedients have been adopted, but I apprehend nothing but a solution of caustic alkali can be depended upon. To prove the effect of any method which may be tried, it is a good way to run the pieces through water, and then to pass them from the water so gradually over a roller, as to give the superintendant an opportunity of examining every inch of the surface; and if any part remains greasy, it will be seen at once, for that part will continue dry, while all the rest of the cloth is wet [59].

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table is not so indelible as that from *animal* oil.

[59] There is another way in which the goodness of bleaching might be proved. Let a few

The next process is one with diluted sulphuric acid. A quantity of soft water having been poured into a leaden vessel, oil of vitriol is gradually added to it, in the proportion of about twenty pounds of oil of vitriol to every hundred gallons of water, which by weight is in the proportion of about one to forty.

When this mixture has been well

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of the suspected pieces be run once or twice through a madder-copper, at the temperature of about 180°. This will inevitably mark any part that may be imperfectly bleached; whereas, if the operation has been properly performed, they will come out so little stained, that an intelligent workman, who has been used to a madder-copper, will at once be satisfied that they contain no impurity that can form a permanent mordant.

stirred, it is ready for use. Sometimes it is employed in this state, at others it is heated to 90° or upwards of Fahrenheit, according to the nature of the work to be done, and the goods are immersed in it. They are not suffered to lie in this solution, but are wound by means of a winch over a wooden cylinder, that every part of the cloth may be immersed in the fluid, and exposed alternately to the action of the atmosphere.

This operation is generally continued for about twenty minutes, and is designed to remove any iron-moulds or other stains which the cloth may have acquired. It has also the effect of neutralizing any portion of potash that may have been left in

contact with the cloth. The process is called SOURING.

After this operation it is necessary to wash the goods thoroughly, that no part of the acid may be left in them, to injure their texture, and this is best effected by means of the wash-wheel. The calicoes are then to be regularly and thoroughly dried, which finishes these preliminary operations, known in the trade by the term PREPARATION; so that those cloths which have passed through these manipulations are said to have undergone a preparation [60].

[60] Besides the uses already mentioned, there is another advantage attending these processes, viz. that the cloth which has undergone this preparation will bleach sooner, the colours

The next process is that of CALENDERING. Here the goods are passed through a set of rollers, which gives them a gloss, and the appearance of their having been ironed. They are now fit for printing [61].

In printing fast colours, the artist usually proceeds in this way: he lays the piece of calico, which has been already smoothed by calendering, upon a strong thick table, which is previously covered with a woollen cloth. He then proceeds to apply one or more mordants, as the case

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will be brighter, and the whites more delicate, than they would have been had they not gone through these previous operations.

[61] For copper-plate printing, or cylinder work, the process of calendering is omitted.

may require, for fixing the intended colours. These mordants are applied by means of wooden blocks, with the patterns formed upon them. These blocks were formerly chosen of holly, and the cutting them was a separate branch of the business, and was called BLOCK-CUTTING. Of late years, however, a considerable improvement has been made in this part of the business by the introduction of brass or copper; that is, the pattern, instead of being actually cut in the wood [68],

[68] When it was customary to use wooden blocks, the patterns were not enchased in the wood, but the wood was cut away in such a manner as to leave the pattern in relief. It will be obvious that this must always be the case in *block*-printing.

is now formed by means of slender pieces of one of those metals being firmly fixed to the block, so as to produce the pattern intended. This alteration was occasioned by the perishable nature of wood, on account of which every printer has incurred great and unnecessary expense. The pattern when thus formed with copper, is not only more lasting, but it has also the advantage of giving greater sharpness and beauty to the impression.

When the mordant is ready, it is mixed up either with flour-paste [63],

[63] Flour is an article of considerable consumption with the printers for making paste. Some houses buy twenty barrels of American flour at once. Should it be musty or sour from

or with a thick aqueous solution of gum arabic, gum senegal, or gum tragacanth [64], and is then spread upon a piece of superfine woollen cloth, strained tight upon a hoop [65]. This is

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keeping, it is of little consequence for their use; but they are careful to buy none but such as has been made with sound wheat, for if unsound it will be of no value for their purposes.

[64] Gum tragacanth is much dearer than the other gums mentioned above; but notwithstanding this, it must be had for some styles of work, as no other will answer for any of those colours or mordants which are prepared with nitrous acid. A solution of gum senegal would be coagulated in an instant by any of those preparations.

[65] Of late years an article called British gum has also been much in use for the same purpose; so much so that the making of it has become a distinct trade. It is merely com-

placed within another hoop, covered either with sheep skin or oil-cloth. These hoops are both so broad as to give to each of them the appearance of a tambarine. That which is covered with the woollen cloth is called a *sieve*, the other a *case*. The sieve within its case is now placed in a small tub of gum-water, and is ready for use.

When the apparatus is thus prepared, the mordant is applied by a brush to the surface of the sieve. This is called TEERING.

It should have been remarked, that when a colourless mordant, like the acetate of alumine, is employed, the

mon STARCH pulverised, and then calcined till it assumes a cinnamon brown colour.

workman generally mixes a little of the decoction of Brazil wood, or of any other fugitive dye, with it. This is called SIGHTENING; and is for the purpose of making the pattern more obvious to the workman, that he may see its progress, and the efficacy of the materials, as he proceeds in printing. The manipulation may be thus described.

Taking the block containing the pattern in one hand, the workman applies it gently to the surface of the sieve, so that a sufficient quantity of the thickened mordant may adhere to the figures. When the block is thus charged, he applies it to the calico, and gives it a blow with a small mallet, either slightly or other-

wise, according to the nature of the pattern.

This alternate application of the block to the sieve and to the calico, is continued till the workman has gone over the whole piece. In this way several different mordants are sometimes applied to the same piece of goods. This is indeed always necessary, when the finished piece is intended to contain a variety of colours, the different colours requiring different mordants to fix them and render them permanent.

The calico is now removed to a room called the stove, where a certain degree of heat is given to it by means of flues, which go round the room on the inside, near the floor. In this

room it is generally continued for at least twenty-four hours[66]. The intention of this is to evaporate the acids used in the preparation of the mordants, and which might otherwise injure the texture, and also to fix the base more surely within the fibres of the cloth.

In this operation an attention to temperature is of the utmost importance. In general the room is kept at about 90°; but an intelligent calico-printer varies this according to the nature of the work under opera-

[66] This is when common red-liquor has alone been printed; but if citric acid or strong muriate of tin has been employed, less time is sufficient, and for the latter seldom more than half an hour is allowed. See vol. i. p. 360.

tion. If iron-liquor has been employed in printing the goods, it is an excellent practice to keep them for several days exposed to the atmosphere[67], after their removal from the stove[68], as the blacks, pompadours,

[67] The iron in an acetous solution is in the state of the *black* oxide; but by exposure to the air it acquires a further dose of oxygen, and the more nearly it is made to approach to the state of the *red* or peroxide, the more fit it becomes for a mordant in dyeing.

[68] It may be worth an experiment to discover whether the colours containing iron would not be better if they were suffered to be only a *very short time* in the stove, but were hung up instead for several days, exposed to a current of air at the temperature of the atmosphere; as the iron would thus acquire the oxygen slower, and consequently would be fixed more firmly within the cloth.

olives, and indeed every other colour prepared with that metal, will increase in intensity; the goods will clean better in the dung-vessels, as will be explained hereafter, and the colours will rise higher and brighter when they come into the copper of bark or madder.

When the pieces have been properly stoved, they are passed, by means of a winch, through water at various temperatures, with a little cow-dung mixed in it[69]. The inten-

[69] This part of the business was formerly conducted in a very uncleanly and negligent way; but of late years some printers have incurred a considerable expense in the construction of their dunging machines, with cocks for hot and cold water attached to them,

tion of the dung is to absorb and remove that portion of the mordant which is not actually combined with the cloth, and which otherwise might stain the white or unprinted parts.

I suspect the dung of the cow is serviceable in another way besides that of cleansing[70], though the printer may not be aware of the nature of its operation. It is acknowledged that madder, cochineal, and some other dyes, produce much better colours

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and thermometers to regulate the temperature. Those erected by Mr. Wright, a very ingenious calico-printer, at Strines, near Disley, are the most complete of any I have yet seen.

[70] To *clean* calicoes by immersion in a dung-vessel, may appear to be a strange phrase; but as this is the technical language of the trade, no other could be employed with propriety.

on woollen than on cotton cloths, owing to the former being of animal, and the latter of vegetable origin. I presume, therefore, that the dung imparts an *animal* matter[71] to the fibres of the cotton, and that this animal matter acts as an additional mordant, and thus more powerfully attracts the colouring particles of the dye, than the mordants alone would be capable of doing[72].

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[71] Berthollet, who analysed the dung of the cow, found in it a substance partaking of the nature of *bile*.

[72] If a piece of calico, prepared with the acetate of alumine, be divided into two parts, and the superfluous mordant removed from one of them by cow-dung and water, and from the other by water only, though both fluids were at the same temperature, it will

The process of DUNGING is an operation that varies in time from five to forty minutes, according to the style of work. The pieces are then taken to the river or wheel, to be more effectually washed; after this they are passed through tepid water, in order that the workman may be assured that every impurity is removed.

His next care is to provide a copper boiler of pure cold water, in

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be found, on passing the two portions through a decoction of weld or quercitron bark, that the yellow will be much more intense and bright in that which had been submitted to the action of the cow-dung. This is a decisive experiment, and I am indebted to a friend for suggesting it.

which a sufficient quantity of madder[73] is put, and a fire lighted underneath it. The calicoes, printed and rinsed as above, are now put into this boiler, and from the time they are immersed, the workman

[73] Madder is one of the most valuable drugs we have, for a variety of purposes in dyeing and calico-printing; as it is the agent by which the best and most permanent blacks are produced; also the finest purples, and every shade of red from a pale pink to a crimson. But perhaps it may not be generally known that this article improves by age. If a quantity of madder-roots be ground, and then packed tight in a cask, so as to exclude the air, and are kept thus for six months, they will then dye a much better colour, and go much further than they otherwise would have done, had these roots been used as soon as they were ground.

never ceases to turn the winch, so as to pass every part of the goods repeatedly through the liquor, till the whole acquires a boiling heat. Indeed, this operation is sometimes continued for ten or fifteen minutes after the bath of madder actually boils, when the pieces are taken out and washed.

This process, which is called MADDERING, has the effect of imparting all the requisite colours to the goods, by means of *one* operation, which may be thus explained.

While one mordant precipitates the colouring matter of the madder to a red, another precipitates a different portion of it to a purple, another precipitates it to a black colour, and

so of every possible shade, from a lilac to a black, and from a pink to a deep red.

If a portion of weld or bark be added to the madder, every shade from a brown to an orange may be produced; whereas, if weld or bark alone be employed, all colours between a dark olive and a bright lemon can be imparted to the cloth. These changes are all occasioned by the play of chemical affinities, and are due to the improved state of chemical knowledge.

Here it may be worth remarking, that whenever it is of consequence to produce the finest yellows or more delicate lemon colour, it is necessary to dry the pieces in the open air, as

the stove would not fail to injure such colours; for stove-drying has always a tendency to convert a yellow to an orange. It is also necessary to be equally careful in the operation of dunging[74] the mordants for these pale yellows; for, should this be done at a higher temperature than 96° or 100°, their beauty will certainly be impaired. There is another advantage in this, viz. by dunging at this low temperature, the dyeing

[74] Since the note at page 126 was written, Messrs. William Grant and Brothers, at Ramsbottom, have also erected a very complete and extensive series of stone cisterns for dunging, on the new plan, well worth the notice of every printer to whom expense is not the first object of consideration.

may be completed even at 110° or thereabouts, which will give a much livelier colour than where a higher temperature has been employed.

The mordants generally used in calico-printing, are acetate of iron for browns, blacks, lilacs, &c. and acetate of alumine for all the different shades of reds and yellows.

Formerly the acetate of iron was made by digesting old iron hoops in sour beer, or in very weak vinegar; but of late years it has chiefly been made with the pyroligneous acid[75], the oleaginous impurities of

[75] If wood be submitted to an intense heat, when inclosed in an iron vessel of any kind with a proper aperture to allow the vapour to pass, this vapour on being condensed forms

which tend, in some cases, to improve the mordant.

Blacks are also produced by the nitrate of iron[76] and gallic acid; the mixture is called chemical-black. This nitrate of iron is made by dissolving metallic iron in a peculiar kind of aqua-fortis. Common aqua-fortis will not

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the acid in question, and is now known to be a kind of impure *vinegar*. The wood in this case is converted into *charcoal*, of which a great deal is prepared by this process, particularly for the formation of gunpowder.

[76] Nitrate of iron was not, I believe, applied to calico-printing till within the last fifty years. This discovery formed an important æra in the trade, as it afforded the manufacturer the means of varying his styles of work in a multiplicity of ways and forms, which, till then, were entirely unknown.

answer for this purpose; for, though it may dissolve the iron with rapidity, part of the metal is apt very soon to precipitate; which not only weakens the colour, but leaves the remainder so acidulous that there is always a danger of such a preparation injuring the texture of the cloth.

It is, however, necessary to remark that the black which is formed by this solution of iron, is produced in a different way from blacks in general; for, when common iron-liquor is used for this purpose, it is first printed on the calico; and when it has been sufficiently oxidized by exposure to the air, the goods are boiled in a decoction of madder, which renders such parts as had

been printed with the acetate of iron an intense black. But the black from nitrate of iron and galls is applied at once to the cloth, and is not afterwards raised by dyeing.

The calico-printer by using a black ready formed is thus enabled to mix it with other colours, in cases where by dyeing alone it could not be produced, as in conjunction with yellows and olives, raised by weld or quercitron bark.

The acetate of alumine is prepared by a mixture of the sulphate of alumine with acetate of lead, both in a state of solution; so that, on the theory of double decomposition, sulphate of lead is formed, which pre-

cipitates, while the acetate of alumine remains in solution.

Since the demand for this article has been increased on account of the extension of the printing trade, it has been prepared from the pyroligneous acid, by means of lime and alum. The following is the method:

The pyroligneous acid is first passed through a still, to divest it of a portion of the tar which is always dissolved in it; it is then saturated with lime or whiting; and lastly, the acetate of lime thus formed, is decomposed by a heated solution of sulphate of alumine. The result of this double decomposition is sulphate of lime, which precipitates, and ace-

tate of alumine, which is drawn from the sediment of the calcareous sulphate, and preserved for use.

And here it may be necessary to caution the manufacturer against a misfortune that may befall him if he be not conversant with the chemical nature of the substances he employs.

Magnesian limestone abounds in Derbyshire and in some of the adjacent counties; and should a maker of acetate of alumine employ such lime in his process, the article which it would produce would in all probability be entirely unfit for the use of the calico-printer. But I must be more explicit.

In employing the common lime in conjunction with alum, a sulphate

of lime will be formed, as mentioned above, and this being nearly an *insoluble* salt, will precipitate. But here, sulphate of magnesia would also be formed, which being a *soluble* salt, would remain in solution, and increase the specific gravity of the liquor, a circumstance which would be very apt to occasion the deception which I am anxious should be avoided. If magnesian lime-stone be employed, the liquor will appear good by the hydrometer; but, as it will contain more Epsom-salt than acetate of alumine, it will be unfit for every purpose for which it was intended.

While speaking of acetate of alumine, I cannot avoid remarking that

the process which has just been described for making this mordant, and which is followed invariably by many of the manufacturers in the North, is extremely improper, on account of the lime which is employed in it, be the lime ever so good, as that earth is very prejudicial to every species of red dye. The true way of making it, though more expensive, is that which was originally pointed out by Berthollet, and which consists in decomposing sulphate of alumine by means of saccharum saturni, or acetate of lead.

In reverting to the remaining processes of the print-work, it must be noticed, that when the goods have passed through the weld or madder-

copper, they are usually carried to a boiler containing wheat-bran and water, in which they are winched for a considerable time, for the purpose of freeing the white grounds from the stain which they had acquired from the madder or the weld. This process always impairs, in some measure, the intensity of the colours [77]; but it is a necessary opera-

[77] Branning has also the effect of giving a pink hue to all madder reds. But it is not generally known what a peculiar richness may be imparted to madder-colours, by raising them with a mixture of bran and madder; that is, by mixing a portion of bran with the madder in the first instance. I have myself sometimes produced colours in this way whose brilliancy has astonished me. The operation of the bran in producing this effect will be explained in the Essay on Dyeing.

tion, as there is no other mode so convenient for removing the stain which is always given to the white part of a print by the madder, the bark, or the weld, which has been used in dyeing it.

It frequently is the case, however, that goods will not bear to be sufficiently branned to clear the whites entirely by that one operation[78]; such goods, therefore, are partially cleansed in the branning-copper, and are then laid on the grass for

[78] The temperature at which the operation of branning is performed, is very important. If bark yellows are dyed at 100°, it is customary to bran such goods at 115° or 120°, as it is a principle always to bran at a higher temperature than the goods are dyed at. Madder-work must be branned at a boiling heat.

some days, till they become perfectly clean.

But, within the last year, a new method has been introduced, which consists in immersing the pieces for a certain time in a very weak solution of one of the bleaching salts, such as oxy-muriate of potash, soda, or magnesia[79]. This simple process, which effects in a few minutes what would require more than as many days in grass-bleaching, is now much practised, and promises very soon to supersede crofting entirely. This is

[79] A Scotch house of great consequence had practised this method a considerable time; and in the year 1812 a person visited Lancashire for the purpose of instructing the English printers in the method.

a most important improvement, as some of the large printers formerly required as much land to spread out their goods upon, as would make a farm of a very considerable size.

Besides the kinds of calico-printing already mentioned, there are others which it will be proper to notice in this place. Of these, what is called resist-work, is now done in considerable quantities. It is conducted in the following manner:

A certain preparation of copper, mixed either with flour paste, with gum, or with pipe-clay and gum, is printed on the calico, in any shape or of any pattern that may be desired [80]. When this is suf-

[80] The sulphate, the nitrate, the muriate, and

ficiently dry, the goods are repeatedly dipped in the blue vat till they have acquired that depth of tint which may be required; and then, when they are washed, and passed through diluted sulphuric acid, those parts which had been printed with the preparation of copper, are found to be a good white; the preparation having effectually resisted the operation of the indigo [81],

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the acetate of copper have all been employed for preparing the resist-paste; but I believe the sulphate is the best for the purpose; unless a very concentrated solution of the four salts were prepared by successively dissolving each of them in pure water.

[81] The art of making an indigo-vat consists in forming such a mixture of lime and sulphate of iron as shall most effectually deoxidize the

though all the other parts of the cloth have received a permanent dye. The various deep blue calicoes with white spots or white figures, which

indigo; as indigo has no affinity for cloth in its natural, or oxygenized state. Hence, those parts of a piece which are printed with a solution of copper will never be dyed blue in one of these vats; because the deoxidized indigo becomes oxygenated the moment it touches the copper, which parts with its oxygen to the indigo, and occasions it to become insoluble, and consequently incapable of forming a dye.

Thus, while sulphate of iron has the power of deoxidizing indigo, sulphate of copper, or any other salt of that metal, is incapable of retaining its ogygen, whenever it comes in contact with that singular substance in a state of deoxidizement; and it is a curious instance of the different degree of intensity by which ogygen is held by the different metals.

are now so common, are generally done in this way; and by a similar management with subsequent dyeing in madder, weld or bark, figures in red or yellow are exhibited upon a blue ground.

In some particular styles of work the operation of certain colours is resisted by means of stopping out with wax; but this is too expensive a method to be adopted often, in these times, when it is the object of every manufacturer to finish his prints at the least possible expense [82]. Formerly

[82] In printing those silk handkerchiefs called Bandanas, a process called waxing is still followed. It consists in making a preparation of tallow and rosin very liquid by heat, and in printing it in that state with a block upon the

this mode was very generally practised, and wax [83] was consumed in very large quantities by this process [84].

The reader will perceive that these *resists* are employed for the purpose

silk. When such goods are passed through the blue vat, those parts which are covered with the tallow and rosin are preserved from the action of the indigo, and remain white, while all the rest is dyed a fast blue. The method afterwards taken to discharge a part of this blue, and produce yellow, orange, &c. will be mentioned hereafter.

[83] In the East Indies wax is still used for preserving the whites in calico-printing.

[84] A very singular-looking substance was discovered three or four years ago near Stockport, which being handed about from one to another, created considerable interest in that neighbourhood. Every body supposing it to be a natural

of preserving certain parts of a piece white, and of giving other varieties to those goods in which blue is the predominant colour: but if the ground is to be white, and the piece is only to have one small object[85] in

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production, specimens of it were sent to a variety of persons into various parts of the kingdom, for their opinion and analysis, and among others a portion was sent to myself. However, after every one had been busily engaged in examination and conjecture, respecting this unknown substance, it was announced, that some seventy or eighty years before, a calico-work had stood on the spot where the article was found, and that this was nothing more than a large heap of the refuse compound of flour, wax, and gum, above mentioned.

[85] A technical term, belonging to this branch of manufacture.

indigo blue, such as a single sprig, then a different management is necessary, and the colour is imparted by a process which is called *pencil-blue*.

Here the indigo is deoxidized by means of orpiment, which is a sulphuret of arsenic; and formerly, whatever objects were done with it were put in by means of a pencil: hence its name, PENCIL-BLUE [86].

The intention in using this preparation had always been to impart

[86] Pencil-blue is composed of the following ingredients, viz. Ten ounces of indigo finely ground in water; twenty ounces of quicklime in lumps; the same quantity of potash of commerce, or the impure sub-carbonate of this alkali; and ten ounces of orpiment. These proportions require one gallon of water, and the whole is to be thickened with gum senegal.

it to the calico, before the indigo had time to recover its oxygen: hence a small quantity only was mixed at once, viz. no more than could be penciled on in a very short time; but the inconvenience which attended this plan, gave rise at length to an invention which has nearly superseded the use of the pencil.

The invention to which I refer is the spring-sieve, which may be thus described: A fine canvass sieve is suspended within a tub of pencil-blue colour, so contrived that the canvass should be in contact with the colour, and follow it as it wasted. But as the colour was consumed the sieve did not always exactly sink with it, which occasioned great un-

certainty, and sometimes considerable disappointment from the admission of too much atmospheric air:—to obviate these inconveniences many schemes were resorted to, but none of them completely answered the purpose.

This utensil has, however, now been much improved by a particular friend of mine, who has kindly allowed me to give a plate [97] and description of it; and I doubt not but I shall have the general thanks of the manufacturers of printed cottons for making public an invention of so much utility and ingenuity. It may be thus described:

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[97] See the plates, fig. 11.

A is the box which contains the colour; B is the sieve which floats within the colour; C. C. C. C. are the four springs which keep the canvass of the sieve close down upon the dissolved indigo; and D is a vessel from which the blue-tub is constantly supplied with colour, as the same is exhausted by the printer, and is upon the principle of a common bird-fountain [88]. The improvement chiefly consists in the addition of this vessel, which, in the beginning, is completely filled with the prepared indigo, and closely corked and sealed,

[88] The stop-cock, which is placed in the tube, is to prevent any loss of colour, in case the barrel should by any accident admit atmospheric air, and cause the box to overflow.

to prevent the possibility of the access of any atmospheric air.

Another kind of process remains to be noticed, called chemical-discharge work. Here the cloth is first dyed of some uniform colour, by means of a mixture of iron-liquor, and some one or more of the common vegetable dyeing substances; and calicoes thus prepared are said to be dyed of self-colours. They are then washed and dried; and when properly pressed or calendered, they are fit for receiving any pattern whatever, according to the artist's taste or design.

This is generally effected by means of the mineral acids, which are pre-

viously composed for the purpose, by dissolving in them a portion of one or more of the metals, according to the nature of the dye which is intended to be discharged, or of the colour to be produced. In doing this, care is taken that the discharging liquor be made so as to be capable of dissolving the iron which is contained in the dye, and which is always used in such quantity as to cover, or at least to disguise in a great measure, the other colour or colours which had been employed with it, and at the same time to act as a mordant in beautifying and fixing those colours.

Thus a piece treated with a de-

coction of Brazil-wood, and dyed black, by being padded [89] with iron-liquor, if, when dried, it be printed with a peculiar solution of tin, the ferruginous portion of the dye will be dissolved, and the printed part will instantly be converted from a deep black to a brilliant crimson.

In the same way an olive-coloured calico, dyed in a solution of iron and a decoction of weld, will as quickly be changed to a bright pale yellow; and the various drabs and

[89] By the term *padding* is understood the operation of passing the pieces from a roller through a trough containing a solution of iron, or any other mordant. *Blotching* is another term used in calico-printing, and is synonymous with padding.

slates of every shade which have iron in their composition, will undergo as sudden a change by the same treatment; though the colour of the figures produced on them will depend on the materials with which the cloths were originally dyed. Even the deepest gold colours, or strongest buffs, if produced by iron only, may, by a peculiar preparation of tin, be discharged; and such parts of the cloth as have been treated with this metallic solution will be restored to their pristine whiteness.

By similar management, calicoes dyed of a light blue in the indigo vat, then run through sumach and copperas, and finished in a bath of quercitron bark and alum, may have

figures of a bright green imparted to them. Here the green is originally formed by means of the indigo-vat and the bark, though it is enveloped by the iron of the copperas, which overcomes the other colours, till the solution of tin is applied, which removes the iron from those particular parts, and gives a brilliancy to the remaining colours which they would not otherwise have possessed; the tin being a powerful mordant for the bark, by which the yellow of the green is produced.

Again, a good self-colour may be given to calicoes, merely by dyeing them in sumach and copperas, and then running them through an alkaline solution of annotto; and here the

figures produced by the application of a colourless solution of tin will be of a bright orange. But it is needless to enumerate more instances, as the workman accustomed to a dye-house will have little difficulty in varying these in a thousand ways, when he becomes acquainted with the nature of the solution of tin which he employs.

The whole of this, however, refers to that branch of discharge-work only, where all the purposes are attained by dissolving the iron which makes a part of the colour that is intended to be discharged; whereas, the finer and more expensive work is done in a different way, and by a process which it will be

necessary for me presently to describe.

In the mean time it may be proper to remark, that there is an objection to the particular kind of chemical discharge-work of which I have been speaking, namely, that it is not perfectly fast; that is, the goods produced in this way will not bear such frequent washing, as those which are done by the bath of madder or bark.

It is certainly an object of great national importance to give a permanency to the calico-printing of the country[90]; and a great deal of

[90] To this end great improvements have lately been made in the method of grinding madder-roots, by separating the inferior parts

very excellent printing is now done in various parts of the kingdom, especially the best chintz-work and other furniture patterns. But, in what is called fast-work, there is a great variety of qualities, and some of it little deserves the name of permanent.

The mention of permanent colours reminds me of a very valuable GREEN which was invented a few years ago by a Mr. Islet of London, and which deserves to be noticed in this essay. This colour, which was

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and dividing the whole into two or three different qualities. Thus the printer is enabled to apply the finest, which in this way is made equal to Dutch-crop-madder, to his best work, and the other is laid by for inferior purposes.

secured to him by His Majesty's Letters patent, was produced by printing ground indigo, mixed with a peculiar kind of solution of tin, and in then fastening the indigo within the fibres of the calico by means of that process, which is well known to printers by the technical designation of *china-blue dipping* [91]. After this the goods are to be dyed in a copper of bark or weld, which converts the blue to a green, and the whites are to be cleansed by croft-bleaching, &c.

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[91] China-blue is produced thus. Indigo ground fine, and then thickened, is printed upon the cloth, and afterwards it is dissolved, and chemically united to the fabric, by alternate immersion in a solution of sulphate of iron and in lime water.

Having myself formed a very high opinion of this invention, I procured several interviews with Mr. Islet, soon after he obtained the patent, and from him was fully informed of the whole process.—This I have since repeated for the purpose of verifying the detail in all its branches; and I am satisfied that it is one of the most beautiful and PERMANENT of colours that has ever been fixed upon cotton.

There is another mode of producing very beautiful blues which has been much practised lately, and therefore deserves notice. This consists in printing some solution of iron, and then passing the goods through a very dilute and neutral solution of prussiate of potash. The prussian blue which is thus formed upon the

cloth may be rendered tolerably permanent by a variety of expedients, and this by means of any of the yellow dyes may afterwards be formed to any shade of green or of olive.

Begging to be excused for the irregularity of these digressions, I must not forget to revert to that other kind of discharge-work which I have engaged to describe, and which I will now attempt as concisely as is consistent with perspicuity and correctness.

Here, the agent which is employed is the citric acid, and this is used in various states of concentration according to the purpose to which it is to be applied, and the strength of the ground intended to be dis-

charged. It is chiefly employed for the production of white figures upon self-coloured grounds produced by madder and sundry other dyes. For this intention the acid, in whatever state of concentration it may be, is mixed with either gum or with paste [92] to a proper consistency for the block, the plate, or the cylinder, and from thence it is transferred to the piece; and wherever it attaches, the mordant, whether iron or alumine, is discharged, and a delicate white arises in its stead [93].

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[92] When citric acid is used for resist-work, it is always mixed with gum senegal and pipe-clay. The clay gives it a greater body, and likewise acts mechanically as a resister.

[93] It should be understood, that the dis-

The acid here referred to is produced from the juice of limes or lemons, and formerly it was not employed by the calico-printer until it was reduced to the utmost point of concentration, and appeared in a crystalline form. Even then, it was not thought sufficiently pure, but was dissolved again, and redissolved and recrystallized, till it became as white and pellucid as any other pure salt in a crystallized state, and was then generally sold for 36*s.* the pound, at which high price it could only be employed on the best styles

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charge is printed upon the mordants before the goods are dyed. In using citric acid for this purpose, a portion of one of the mineral acids is sometimes mixed with it.

of work. Now, however, it is oftener used in the brown, or first state of crystallization; and some of the larger printers purchase lime juice, and concentrate it themselves; and in many cases they use it largely both for discharge- and resist-work, without ever crystallizing it at all. More on this subject may be seen in the Essay on Citric Acid, and which was written with the hope of rendering an essential service to a large body of manufacturers, with whom I have great intercourse, and to whom I am under very considerable obligations.

This mention of discharge-work by citric acid[94], reminds me of another

[94] Mr. Thomson, who has a print-work

species of discharge, which is employed by the printers of Bandana handkerchiefs, and which I am under the promise of noticing before I conclude this Essay.

The agent which these printers employ is the nitrous, and sometimes the nitro-muriatic acid. It is used for the purpose of putting yellow figures upon blue silk handkerchiefs. The following is the process which is principally adopted.

Aqua-fortis, or nitro-muriatic acid, of such a strength as is suitable for

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near Clitheroe, has lately taken out a patent for discharging the Turkey-red dye by means of the citric and oxy-muriatic acids; and the work executed in this way has a very pleasing effect.

the kind of blue which is intended to be discharged, is mixed either with gum tragacanth, or with flour paste, to a proper consistence, and in this form it is printed on the silk, by means of a common block, on which the intended pattern is cut. The consequence of this is, that wherever the acid attaches, there the original colour is discharged, and a yellow dye is produced in its place. The pieces are then steamed, by passing them over a vessel containing boiling water, which gives brilliancy to the colour and finishes the operation.

If a stronger dye than the usual yellow, or even a deep orange be desired, all that is necessary is to immerse the goods, for a moment, in

lime water, or in a solution of lime and potash; and by varying the proportions of these ingredients a great variety of shades may be produced.

Recollecting, however, that this is a paper professedly on *calico*-printing, I must not deviate too far from the path I have prescribed; otherwise, there are many processes in the printing of silks which are curious and interesting, on which I might copiously expatiate.

Having been speaking of yellows, it may be worth mentioning, that there is a mode of producing yellows on calico which is not very frequently practised, and yet has a very good effect. The process is as follows:

A strong decoction of bark, thicken-

ed with gum tragacanth, is to be mixed with a portion of very pure muriate of tin, and this, when printed with the usual management, will produce a colour of great brightness and durability. I mention this the rather, because very many pleasing effects may be obtained by this method which cannot be produced in the usual way, by means of the acetate of alumine, and any of the yellow dyes that may be employed with it.

There is one very important advantage which this mode possesses, viz. that should it be necessary to pad a piece in diluted acetate of alumine to obtain a pale lemon ground, the yellow figures, pre-

viously done by the above process, will not give out any part of their colour to the second mordant; whereas, whenever a strong yellow has been produced in the common way, the pattern is very apt to spread and become irregular, and oftentimes to stain the ground, when the piece comes a second time into the acetate of alumine.

Nothing now remains but to notice an improvement which has been made of late years by the introduction of CYLINDER-PRINTING, and which has the advantage of superior accuracy and neatness, as well as of great expedition.

The machines which effect this are rather complicated and expensive;

but they are so contrived that the cylinders on which the patterns are engraved, furnish themselves with colour during their revolutions; are kept clean by a steel knife, or *doctor* as it is called, passing over their surfaces the moment they have charged themselves with the thickened colour; and they have such a pressure given to them, either by means of screws or levers, which can be tightened or slackened at pleasure, that the whole surface can be made to deposit its colouring matter with the greatest certainty and exactness on the cloth, while this rolls over it in succession, from one end of the piece to the other.

These cylinders, which are made

of copper[95], are from eighteen to forty-two inches in length, according to the width of the calico to be printed, and three and a half to five inches in diameter; and these massy rollers have the patterns enchased upon their surfaces, in the same way as a pattern is cut upon a flat plate of copper, that is intended to be employed in copper-plate printing.

Many of these machines are now

[95] As these cylinders are made with plates of copper hammered into a circular form and joined by brazing, great loss has sometimes been sustained by the engraving giving way upon the brazed joint. To obviate this, a patent has, I understand, been lately obtained for boring the copper cylinder from the solid metal in the modern way of boring cannon.

contrived so as to carry two of these cylinders, each of which has a trough of colour attached to it, by which means two different colours may be printed on the same calico, at one and the same time[96].

These machines have not only the excellence of printing more correctly than can possibly be done by means of the block, but the saving of time and labour which they afford is great indeed. A piece of calico which would take a man and a boy three

[96] Mr. Adam Parkinson of Manchester has lately invented a machine capable of printing at one time, by means of one cylinder and two surface rollers, or by two of the former and one of the latter, three distinct colours. See the plates, figure 12.

hours to print with one colour, or six hours to finish with two colours, may by this means be done in three minutes, or three minutes and a half, and then much more completely than could even have been imagined before the introduction of this invention.

Besides these cylinders there are others which are called SURFACE MACHINES, which contain cylinders of wood, and which have the pattern formed upon their surfaces in relief, exactly similar to the blocks described in page 118. These are employed in particular styles of work, especially in light ground-work [97],

[97] In light work, the white grounds are apt to be soiled by the cylinders: hence surface-

and for certain kinds of resist- and discharge-work.

It must be obvious to every one who is acquainted with the subject, what an astonishing facility these machines have afforded to the production of printed calicoes; and also what an advantage they will give to the British printer in foreign markets, whenever the world shall be blessed by the return of a general peace.

But I cannot conclude without expressing my fears, that even these facilities may eventually be the means

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machines were contrived, and these have not the same objection. Cylinder-machines are more commonly employed in those styles which are full of colour and leave but little white.

of doing a serious injury to the trade, and of destroying that confidence in the goodness of British prints, which has hitherto been generally felt in every market on the continent, and also in every part of the New World, wherever they have been introduced.

I refer here to that mode of printing which has lately been adopted, and which consists in precipitating the colouring matter from logwood, and from other *fugitive* dyes, and in printing these on the cloth, without any mordant or previous preparation whatsoever. Thousands of pieces of this sort are, I suspect, now under the hands of the workmen, and will be finished at the low rate of one

penny the yard, including every expense of colour, paste, and printing. These articles, it will scarcely be credited, are dried up immediately from the printing machines, and are shipped abroad, without even being washed off[98].

Such goods, wherever they go, must produce great dissatisfaction, for they will neither endure the rays of the sun, nor moisture. The first shower of rain to which they may be exposed, will not fail to wash out

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[98] To *wash off*, is a technical phrase. It means the soaking and rinsing the pieces in water, in order to dissolve and remove whatever gum or paste had been employed with the colours in printing them.

the pattern, and reduce them to a worse state than that of plain white calicoes.

In the reign of Queen Elizabeth, an Act was passed to restrain the use of logwood [99] in dyeing, on account of the fugitive nature of its colour; and if this degrading kind of printing be continued, the interference of the Legislature will again become necessary, or the foreign trade will, from this cause alone, be entirely lost to the country.

I consider it to be my duty to throw

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[99] In the time of Queen Elizabeth the nature of logwood was not understood; but now it has many important uses, and when properly employed is one of the most valuable articles used in dyeing.

out the hint at the conclusion of this Essay, and shall have great reason to rejoice, should it be possible that I may be the humble means of averting such a calamity.

ESSAY V.

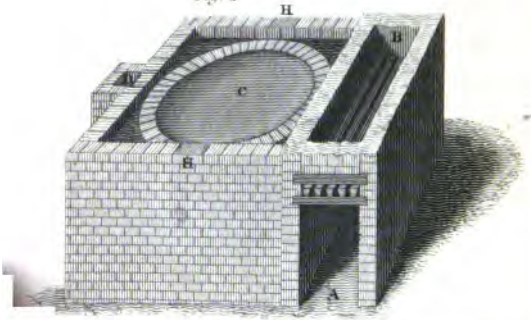
ON

BARYTES.

A Barytes Furnace

Fig. 1

Fig. 2



Jas. Davis sculp.

ESSAY V.

ON

BARYTES.

In the year 1774, Mr. Scheele made some experiments on a mineral called baroselenite, which he found to be a combination of sulphuric acid and a peculiar alkaline earth never before described. Gahn also minutely examined this mineral about the same time, and both these chemists agreed to denominate the base of it "heavy earth." Mr. Scheele immediately published an account of

Derbyshire lead mines[4]; in the Cornish copper mines; at Roye in the province of Picardy in France; in the vicinity of Mount Etna, and in a variety of other places[5]. It is the heaviest native salt with which we are acquainted.

It is composed of 13 parts sulphuric acid, 84 parts barytes, and 3 of water; whereas the sulphate of barytes which is formed by art consists of 33 sulphuric acid, 64 barytes, and

[4] The mineral is known to the miners in Derbyshire, by the name of *cauk*.

[5] "Sulphate of barytes, in veins nearly four feet wide, traversing the sand-stone, is found in the Isle of Arran, at a small distance from the shore. Also at Pomona in the Orkneys." Jameson's Mineralogy of the Scotish Isles, 4to, 1800, vol. i. page 71, and vol. ii. page 232.

3 of water. The native
frequently of a flesh col
foliated texture; but it
in a great variety of for

A species of this min
about the Apennine mo
in several other parts of I
pieces about the size of
a light gray colour and
face. These have ofte
appearance of some
species of sulphate of
after heavy showers of

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[6] Very beautiful specimens
barytes may be procured fro
fuller's earth pits, at Bletchi
stone in Surry. The workm
rally in loose pieces in the mi
fuller's earth. They call it sh

wash away the earth from the mountains, they are found in abundance [7].

These little nodules, which are called *Bologna stones*, are remarkable for acquiring a phosphorescent quality by calcination. Lemery relates, that this property was discovered by one Casciarolo, an Italian shoemaker, who picked up one of these stones at the foot of Mount Paderno, four Italian miles from the city of Bologna [8].

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[7] Busching's Geography, vol. iii. page 139.

[8] Benvenuto Cellini, in his Art of Jewellery, mentions his having seen a carbuncle shine in the dark like coals nearly burnt out, and relates a story of a coloured carbuncle having been found in a vineyard near Rome, by the circumstance of its shining in the night.

This man, imagining from its weight and colour that it contained silver, submitted it to calcination, to extract, as he thought, the precious metal: and though he was disappointed in this respect, he discovered that the action of the fire had given it the property of being luminous in the dark; and that not only this particular stone, but others [9], which he afterwards treated in a similar manner, acquired the same property [10].

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[9] An account of a variety of phosphorescent bodies may be seen in the Phil. Trans. for 1792, page 28 &c.

[10] There is a paper on the preparation of the Bolognian stone in the Philosophical Collections for 1681, published by the Royal Society of London, page 77.

It has been said that these stones retain their luminous quality even when laid under water; that their splendour usually lasts three or four years, and that it may then be renewed by a fresh calcination [11]. If so, I would suggest whether they might not be usefully employed by the workmen in those dark and intricate passages in certain coal-mines which abound with carburetted hydrogen gas [12], and where the introduction of a candle might produce a dreadful explosion [13].

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[11] See Busching, vol. iii. page 140.

[12] Another expedient for lighting such mines is mentioned in the Essay on Temperature, vol. i. page 209.

[13] For the best method of making Bologna

I am not aware that the native sulphate of barytes is used at present for any other purpose than preparing the Bologna phosphorus, and for the extraction of pure barytes by means of charcoal and the nitrous acid. It was, however, pretty largely employed some years ago by that ornament of our country, the late Josiah Wedgwood, in the manufacture of his beautiful jasper ware, which rivalled the productions of antiquity, and found its way into the mansions of all the votaries of taste in every corner of Europe.

From the employment of the sul-

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phosphorus, see Lagrange's Chemistry, vol. i. page 188.

phate of barytes in this way, Mr. Wedgwood, for a long time, derived great profit; none of the workmen having any idea of the nature of the material on which they were operating; until a letter containing a bill of parcels of a quantity of the article fell unfortunately into the hands of a faithless servant, who sold the secret, and deprived the worthy inventor for ever of that particular source of emolument. For, when the article came to be manufactured by those who employed inferior workmen, to whom they perhaps did not pay one fourth of the salary which was given by Mr. Wedgwood, the price of jasper was so reduced that it was no longer in his power

to employ his exquisite modellers on that branch of the manufacture.

The artificial sulphate of barytes has for many years been applied to the purposes of painting in water colours, and is the most delicate and perfect WHITE in use. It was first recommended and brought forward by Mr. Hume of Long Acre, who has long supplied the public with it under the name of *permanent white* [14]. The native and artificial sulphate of barytes are both poisonous.

If the native sulphate of barytes,

[14] I know of nothing so well calculated as this for marking bottles in a chemical laboratory, where the gases soon destroy the ink of common labels, and render them illegible. It is equally useful for marking jars, bottles,

reduced to powder, be mixed with a large portion of charcoal, and submitted to a red-heat during the space of several hours, the sulphate will at length be converted to a sulphuret of barytes, and the sulphur may afterwards be precipitated by acetous acid. The acetate of barytes may then be evaporated to dryness, and a moderate heat will dissipate the acid, and leave the barytic earth nearly in a state of purity.

The following direction is given by Mons. Brisson, the French pro-

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or boxes which must be kept in a damp cellar; for it is not only imperishable in such situations, but preserves its extreme whiteness, and consequently the distinctness of the characters.

fessor of chemistry. "Pulverize," says he, "sulphate of barytes, and calcine it in a crucible, with an eighth part of its weight of charcoal dust; keep the crucible at a red-heat for about an hour, and then pour the matter into water: the water will assume a yellow colour, and exhale a strong odour of sulphuretted hydrogen gas: then filter the liquor, and pour into it muriatic acid: there will be formed an abundant precipitate, which must be separated by a second filtration. The liquor that passes through the filter holds in solution muriate of barytes, which is formed by the addition of the muriatic acid. If you then add liquid carbonate of potash, the pot-

ash will combine with the muriatic acid, and the barytes with the carbonic acid, from which it may be freed by calcination: what then remains is pure barytes."

For nine years after the discovery of barytes by Scheele, the chemists of Europe were unacquainted with any other source for the production of this alkaline earth, besides the ponderous spar of which we have been speaking, till Dr. Withering, a physician of Birmingham [15], an-

[15] This gentleman is known to the literary world as the author of a useful treatise on botany, entitled "A botanical Arrangement of all the Vegetables naturally growing in Great Britain," 2 vols. 8vo. a work which has since been enlarged by Dr. Stokes, an eminent physician at Chesterfield in Derbyshire.

nounced that among the minerals in Mr. Bolton's cabinet he had discovered a specimen of native carbonate of barytes, which was found in a lead-mine on Alstone moor, in the county of Cumberland. This discovery was made in the year 1783, and the particulars attending it were published in the Philosophical Transactions for the year 1784.

This mineral was first called *Witherite*, from the name of its discoverer; afterwards *mephite of barytes*, *chalk* of barytes, *aërated heavy earth*, *aërated barosełenite*, *aërated ponderous spar*, &c., and Lavoisier named it *carbonate of barytes*, which is an appropriate term, and that which it has borne ever since. Its specific gravity is 4,330.

Not long after this discovery of Dr. Withering's, it was found that a similar mineral existed in abundance in the lead-mines of Anglezark in Lancashire; and while these mines were worked, the chemists of Europe might have been supplied with any quantity of this native carbonate [16].

[16] From a remark made by Leigh, it appears that these mines also contain sulphate or sulphuret of barytes; for, speaking of a *black mineral* found there, and which affords a diverting phænomenon, he says, "If you calcine this spar in a crucible, its sulphureous particles so diffuse themselves in the ambient air, that the persons standing by, by their paleness, resemble the corpses of so many deceased persons." Leigh's Lancashire, fol. Oxford, 1700, page 71.

I have likewise understood that carbonate of barytes has been found in some one district of Scotland, and also in Sweden; although, when the intercourse between France and this country was last suspended, it had not then been discovered in any part of that kingdom [17].

The native carbonate of barytes, according to Pelletier, consists of carbonic acid 22 parts, of barytes 62, and of water 16 parts; but the factitious carbonate is a compound of 7 parts of carbonic acid, 65 of barytes, and 28 of water.

Those who have done most in in-

[17] I learn this from a remark made by Guyton and Carny, page 112 of the 19th volume of the Annales de Chimie.

vestigating the nature of this earth, since the discovery by Dr. Withering, are Pelletier, Vauquelin, and Fourcroy in France, and Mr. Hope of Edinburgh [18].

With the view of ascertaining whether any quantity of carbonate of barytes could now be procured, provided a method could be devised of bringing it into use in the manufactures of these kingdoms, I, on the first of August 1810, visited the once celebrated mines of Anglezark in the hundred of Salford, which are situated near the town of Chorley, in the county of Lancaster.

[18] See Annales de Chimie, tom. iv. page 62; tom. xxi. pages 113 and 276. Also the Edinburgh Transactions, vol. iv. page 36.

On inquiring at Chorley, I found that the mines are in so obscure a part of the country [19] that it would be necessary for me to take a guide with me; and I was so happy as to meet with a gentleman of fortune in the town, who very kindly offered to accompany me and conduct me thither.

From the town of Chorley you go about a mile on the turnpike road to Bolton, and then turning off to the right, proceed through a very rough stony lane, which brings you near to the village of Limbrick, which is

[19] These mines are in the midst of the moors, at a considerable distance from any turnpike road, about eight or nine miles from the town of Bolton, and three from Chorley.

about two miles from Chorley; and then passing over some romantic fields, you arrive at the house of Banister Derbyshire, a fine old man, nearly three score and ten years of age, who occupies the estate where the mine is situated.

This man, who knows more of the history of these singular mines than any one in the neighbourhood, walked with us to the spot, and showed us the places which were formerly occupied for the different purposes connected with the working of the mines.

From him I learnt that all these are *lead*-mines, which were in full work more than a hundred years ago; and that having been shut up, were

again opened, long before his time, by Sir Thomas Standish, the father of the present proprietor.

From the appearance of the land, it is evident that there have formerly been a great number of shafts for drawing up the minerals; and on making inquiry as to this point, our guide informed me that he was sure he could show me forty at the least; whence I conclude that a large quantity of lead ore must some time or other have been raised.

About thirty years ago these mines were opened a third time by the direction of Sir Frank Standish, who drove fresh levels from the foot of the several hills, into the heart of the mine, in order to carry off the water,

and enable the men to work: but having engaged several different sets of workmen, who all conspired to defraud him of their time, and endeavoured to impress his mind with an idea of the small quantity of ore that could be procured, at the moment when they were practising various arts to induce him to lease the mine to them, he became tired of mining; and about the year 1790, when he had sunk some thousands of pounds in the undertaking, the work was again discontinued, and all the miners dismissed.

It is apparent that the proprietor had no idea of working these mines again, for every thing about them is gone to ruin. Our guide showed us where

stood the large water-wheel for winding up the water from those parts of the mine that could not be drained by the levels; which was the site of the warehouse for storing the washed ore; and where stood the smithy for repairing the tools of the workmen: but there is now scarcely a square yard of walling of any of these buildings left standing entire.

Knowing that we are all the victims of habit and the creatures of circumstance, I could not help fancying, while exploring this forsaken domain, what a different character the proprietor of these mines might have been, had he been so fortunate as to have had a different sort of education, and, in his youth, had

imbibed a taste for literature and science: for, had this been the case, he might now have been as eminent for the accurate investigation of the treasures which nature has hidden within his most valuable estate, and for other useful and scientific pursuits, as he has been through a long life, for his skill on the turf at Newmarket, and other rendezvous for the votaries of the goddess of fortune[20].

The quantity of carbonate of barytes in these mines is immense, much greater, I understand, than that of

[20] Sir Frank Standish died since this Essay was written; and it is expected that the valuable estate including the mines of Anglezark will devolve to a youth now about 12 years of age.

the lead ore (five to one, as our guide supposed); but as the metallic ore was raised, this was always left behind in the mine, being considered of no value. The workmen called it spar.

Some of the best-informed people in the town of Chorley say, that the first time any idea was given of the value of this spar, was by the arrival of two Frenchmen about twenty-eight years ago. It appears that they were in the town some days without the nature of their business being suspected, till it was at last discovered that they had been at the lead-mines, and had filled two boxes with the spar, which they secured with

great care, and sent off by the carrier before they left the town.

At this, Mr. Tatham, the steward of Sir Frank Standish, immediately took an alarm; and having given strict orders that in future no one should be suffered to take away any of the spar, set himself to make every inquiry he could into its nature; to learn, if possible, to what uses these foreigners intended putting it; and whether some methods might not be discovered for consuming it in this country. In prosecuting these objects of inquiry, however, he never succeeded.

The papers in the Philosophical Transactions by Dr. Withering and

Mr. Crawford[21] on the carbonate of barytes had now drawn the attention of all the chemists of Europe to this newly discovered mineral; so that its real nature and properties were every where soon understood. But during this investigation, in which every chemist who was fortunate enough to procure specimens was probably engaged, nothing new occurred at the mine or in the neighbourhood respecting it, till it was discovered that a man of the name of Smithels, who occupied a cottage and about forty acres of land under Sir Frank Stan-

[21] Mr. Crawford's ingenious paper is professedly on the muriate of barytes, which he formed from the solution of this mineral in muriatic acid.

dish, close to the mines, had long been engaged in disposing of the carbonate of barytes in an illicit manner.

This man, who was well known in the neighbourhood of Chorley, and is still remembered by many of its inhabitants, used to get the spar from among the heaps of stone and rubbish that lie round the mouths of the old shafts. This he used to pack in strong boxes, and delivered them himself, by his own cart, to the carrier in Chorley, to be conveyed to Liverpool.

He managed this business so well, that he not only bought the boards for making the boxes, but prepared the boxes himself in the night, and

suffered no one to see him pack the article, or carry it away when packed. Besides, it went from Chorley by the common carrier to a broker in Liverpool, who shipped it to a middle-man upon the Continent;—so that the place where it was actually consumed could never be traced out.

A neighbouring farmer had, indeed, for some years observed that James Smithels was often engaged in picking something from off the waste land; and that often on moonshine nights, when they imagined no one observed them, he and his wife were employed for hours together upon the mounds which stand round the old shafts; and on the circumstance

being mentioned to the steward of Sir Frank Standish, he put an entire stop to this poor man's little trade.

However, when he was questioned by the steward, and by a variety of other persons, respecting this transaction, he remained sullen and silent, and would never give them the least information as to the quantity he had sold, the price he had obtained for it, or even to what part of the world it went. It was, however, imagined that the two foreigners before mentioned were the people who had engaged this man to collect it, and that they had found some means of regularly paying him for what he procured for them.

As the quantity of carbonate of

barytes thus collected, was much larger than merely to serve as a chemical test and a few common purposes of philosophical research, I was desirous of ascertaining something more, if possible, respecting this traffic in the Anglezark spar; and from one Alexander Gerrard[22], an intelligent farmer, who resides not far from the mine, and was formerly very intimate with the aforesaid James Smithels, I learnt the following particulars.

That Smithels, only a short time

[22] I have entered upon this detail, and given the names of these men, in order that, if any persons should wish to prosecute the inquiry, they may know to whom to apply for information.

before he died, informed Gerrard that, in the whole, he had sold a very large quantity of the spar; that he received five guineas per ton for it; that it went from Liverpool to some part of Germany; and that he had understood, from the person who usually paid him, that it was consumed in some process in the manufacture of porcelain [23].

Being desirous of knowing whether these poor uneducated men had

[23] This circumstance has induced me to write so full an account of this transaction, in the hope that some of our manufacturers of earthenware will be tempted to persevere with experiments on the native carbonate of barytes, till they discover an advantageous method of employing this mineral in some branch of their manufactory.

any idea of the nature and properties of the carbonate of barytes, I put some questions to them for that purpose. They told me, all they knew of it was, that it was a strong poison.

On my affecting ignorance of the poisonous nature of this mineral, Mr. Derbyshire assured me that some years ago, he lost three cows at one time, who had strayed from their pasture, and were found licking some lumps of the spar, which at that time lay about the mine in abundance; and that on opening one of these animals, several small pieces of spar were found in its stomach.

He told me also, that it was impossible to keep any fowl upon the farm; for, mistaking the smaller pieces

of the spar for white sand, they were sure to pick it up, and die the first day they got out upon the land. Ducks and geese, he says, he can keep, as they do not swallow it, except at the time they lay their eggs, and then they never fail to take it, and with the same baneful effect. Doubtless they mistake it for lime or chalk, which all oviparous animals are obliged to swallow at the time of their laying, in order to shell their eggs[24].

It has been doubted whether the carbonate of barytes be a poison to

[24] If fowls be pent up in a situation where they are deprived of all calcareous matter, it is well known that they lay their eggs without shells.

the human species; but on examining Leigh's History of Lancashire, written more than a century ago, to see if these mines were noticed by him, I find the question answered in the affirmative. This is what he says upon the subject, when speaking of these mines, and of this spar.

"The neighbours thereabout will frequently take a scruple at least of this in fits of the stone, in whom it vomits and works violently by urine, affording great relief. Some have been hardy enough to take a drachm at one dose, particularly one James Barnes's wife and child, and in about nine hours afterwards they expired. The like quantity, in about three

hours time, will kill a dog[25]. Nay, so spreading is the poison of this spar, that it has not only been fatal to the creature that has taken it, but a dog, by licking the blood of a hog which had accidentally taken it, mixed with meal, expired likewise[26]."

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[25] "Messieurs Huzard and Biron gave to some horses the muriate and carbonate of barytes, in doses of 118 grains English, every day; and these animals died suddenly, after having taken them for a few days." "A dog, which Pelletier caused to swallow 20 grains, was seized with vomiting, and died within eight hours afterwards." Chaptal's Chemistry applied to the Arts, vol. ii. page 70. Nicholson's Journal, vol. i. 4to, page 529.

[26] Leigh's Natural History of Lancashire, folio, Oxford, 1700, page 70.

In consequence of these accidents, this spar has, in the district where the mines are situated, obtained the name of *rats-stone.*

Mr. Pelletier relates, that the Society of Health at Paris was engaged in ascertaining what advantages medicine might derive from the use of barytes; and that both the muriate and carbonate of this earth were given to horses seized with that highly infectious disease called the *farcy,* for which corrosive sublimate is generally administered; and that both these medicines, viz. the carbonate and muriate of barytes, given to different horses, in the quantity of two drachms a day, seemed for a while to have effected such a change

that they were even considered as cured at the end of a fortnight, and nevertheless they both died within a few days of each other[27].

Dr. Withering observed the difficulty there is in decomposing the native carbonate of barytes, and that when submitted to a strong heat it sooner fuses than parts with its carbonic acid. But Dr. Hope having announced[28] that when he submitted it to an intense heat in a black-lead crucible, the carbonic acid was separated, though in an earthen cru-

[27] Annales de Chimie, tom. xxi. page 113, or Nicholson's Journal, 4to, vol. i. page 529.

[28] Dr. Hope published his experiments in the year 1793, in the Edinburgh Transactions, vol. iv. page 36.

cible it permitted nothing to escape, Mr. Pelletier was induced to try the effect of mixing it with charcoal before he heated it, and by this means he obtained barytes tolerably pure and soluble.

Mr. Fourcroy, who has related this circumstance, confesses that the theory of the experiment is unknown to him[29]; but may it not be attributed to the charcoal combining with the carbonic acid of the carbonate of barytes, and with it forming carbonic oxide[30], which is a gas

[29] Fourcroy's System of Chemistry, vol. iv. page 14.

[30] Carbonic acid contains only 18 per cent. of carbon; but carbonic oxide contains 40 per cent.

lighter than atmospheric air, and very highly combustible?

If, however, barytes perfectly pure be required, it can only be obtained by dissolving the native carbonate in diluted nitric acid, evaporating the solution to a salt, and then decomposing this salt by heat.

Neither concentrated nitric nor muriatic acid has any effect in dissolving carbonate of barytes, as was first shown by Fourcroy[31]; but he was mistaken in asserting that this earth "forms with all the acids the most permanent compounds, and the most difficult of all to be decomposed," since it is true only of those

[31] Annales de Chimie, tom. iv. page 62.

acids which form with barytes *insoluble* salts; for, if it be employed to decompose common salt, it only produces a partial decomposition, and may be precipitated again from the acid, by means of either of the carbonated fixed alkalies[32].

When I first made nitrate of barytes in quantity, I took the following proportions:

	lb.
Nitr. acid of the sp. gr. of 1,250,	2
Water	8
	10

I mixed the acid and water very carefully, and then the sp. gr. of the mixture was when cold 1,0528.

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[32] Ibid. tom. xlix. page 95. Nicholson's Journal, vol. xviii. page 68.

To this diluted acid I added one pound of carbonate of barytes, and submitted the whole to a gentle heat. The acid dissolved the barytes with rapidity; but when the action had ceased, I found a large portion of residuum, which was chiefly a nitrate of barytes, in a crystallized state[33]. To dissolve this nitrous salt I added more water, by degrees, till sixteen pounds were employed; when the

[33] Some years ago Mr. Hume noticed a peculiarity attending the nitrate and the muriate of barytes, which is, I think, worth recording. He discovered that these salts are entirely *insoluble* in the respective acids of which they are formed. It should, however, be remarked that this is not the case with sulphate of barytes, for this is perfectly *soluble* in its own acid. Phil. Mag.

only residuum remaining, was one ounce of the carbonate of barytes, which the nitrous acid was incapable of taking up. The materials used, and the amount of the produce, then stood thus:

	lb.	oz.	
Nitrous acid	2	0	at 1,250
Water . .	24	0	
Carb. baryt.	0	15	
	26	15	

Produce.	lb.	oz.
Sol. nitr. baryt. sp. gr. 1,0507	22	6
Loss by evaporation . . .	4	9
	26	15

Finding that so large a portion of water is necessary for holding the nitrate of barytes in solution, the process which I have since adopted has been the following:

Nitrous acid, 2lbs. at 1,250; water,

24lbs. When mixed, the sp. gr. is 1,0156; to this diluted acid I add 19oz. of carbonate of barytes, and though the acid is so very much diluted, it immediately acts upon the earth and dissolves it rapidly, even in the cold. When submitted to a gentle heat the solution goes on with greater rapidity, and in about an hour the whole is dissolved. The produce is generally as follows:

	lb.	oz.
Sol. nitr. baryt. sp. gr. 1,0600	22	14
Loss by evaporation, &c.	4	5
	27	3

It will be observed that there is not only less trouble, but an economy, in thus diluting the acid, for it prevents in a great measure its evaporation.

In preparing the muriate of barytes, I have generally used very weak muriatic acid of the specific gravity of 1,0612, which may be formed by mixing muriatic acid at 1,170 with double its weight of pure water. In this menstruum I dissolve the carbonate of barytes to the point of saturation. Twenty-four pounds of this diluted acid, is capable of dissolving exactly six pounds and a half of the native mineral, and the solution of the muriate of barytes will be of the specific gravity of 1,260[34].

The poisonous nature of barytes,

[34] Dr. Crawford has written on the properties of the muriate of barytes. His paper is in the second volume of the "London Medical Communications," page 301.

by which it differs from all other earths, has been mentioned; but its most distinguishable property is the facility of its crystallization when dissolved in water, and which decidedly marks it to be very different from lime, which is sparingly soluble in water, and does not form crystals when it separates itself therefrom. Notwithstanding this, Margraaf asserted that the base of ponderous spar is calcareous earth; misled, doubtless, by its affinity for sulphuric acid, and by some other properties in which it does actually resemble lime[35].

At one time this earth was con-

[35] See Bergman on Elective Attractions, page 180.

founded with strontian, and many chemists were at a loss to know whether there was any real difference between the two minerals; but an important series of experiments made by Pelletier, in the year 1796, has put this matter beyond all doubt, and established them as two distinct substances[36].

Any person may, however, easily satisfy himself of the difference of this earth from every other, by the test of prussiate of potash, which will

[36] The paper which gave an account of these experiments was read before the National Institute, April 30th, 1796; and afterwards published in Annales de Chimie, tome xxi. page 113, &c. A translation of it may be seen in Nicholson's Journal, 4to, vol. i. page 518.

instantly separate barytes from its combination with the nitric or the muriatic acid; and I believe no other earth is separable from either of these acids, by the same means.

Water at the temperature of 50° takes up about a twenty-fifth part of its weight of this earth in its caustic or pure state; the solution remains transparent and colourless, and is known in the laboratory of the chemist by the term *barytic water*. It is necessary to keep it in bottles well closed, otherwise the earth will acquire carbonic acid from the atmosphere, and separate itself from the water of solution, as lime does in similar circumstances, and appear as a pellicle on the surface.

The best method of preserving barytes in a state of purity, is to dissolve it in warm distilled water, and if, during the heat that is generated by the slacking of the earth, the water be saturated with it, an abundance of needle-shaped crystals will be procured when the whole has become cold. These crystals should be kept in well stopped bottles, for the purpose of making barytic water as it may be required.

An acetate of barytes has also been found to be a convenient preparation of this valuable earth. This may be readily made by dissolving the native carbonate in acetic acid, and by spontaneous evaporation the solution will deposit very beautiful

prismatic crystals of acetate of barytes, which will not deliquesce in the atmosphere.

When I first made acetate of barytes, I proceeded thus: To twelve pounds of acetic acid of the spec. grav. of 1,0420 I added four pounds of carbonate of barytes, and submitted the vessel containing it to a gentle heat. To dissolve the carbonate of barytes in acetic acid, it is only requisite to have the acid a little warm; 90° of Fahrenheit will be quite sufficient, till the acid approaches the point of saturation, and then it will be advisable to give it the heat of 130°.

When the action has ceased, and the whole become cold, I poured

the solution from the residuum, and found a large portion of crystals of acetate of barytes among the carbonate which remained undissolved. Two pounds of water, however, were sufficient to dissolve these crystals; and when the whole of the solution was filtrated, and the residuum dried, one pound three quarters of the carbonate remained; so that the materials used and the produce obtained stood thus:

	lb.	
Acetic acid	12	at the sp. gr. of 1,0420
Water . . .	2	
	14*	
Carb. of barytes	2¼	
	16¼	

* If the two pounds of water had been added to the acetic acid in the first instance, the spec. grav. of the mixture would have been 1,0380.

Produce.	lb.
Sol. acet. barytes at 1,1870	13
Loss by evaporation	3¼
	16¼

Finding that the acid which I used was capable of dissolving more barytes than it could hold in solution, I have since adopted the following process, which I recommend as the best that I have been able to discover for making the acetate of this earth:

	lb.
Take Acetic acid at 1,0420+ . . .	12
Pure water	12
Carbonate of barytes well washed	2½
	26½

+ The specific gravity of equal parts of such acid and water, when mixed, will be 1,0260; therefore acetic acid, which may originally be of a strength about equal to this specific gravity, will be very proper for this process.

The produce will be	lb.
Sol. acet. baryt. at 1,1480 . .	21
Probable loss by evaporation . .	5½
	26½

Whether the barytic salts are used in medicine, or as chemical reagents, it is of the utmost consequence to have them made uniformly the same. I have therefore thought it worth while to give these experiments in detail, in order to furnish, by means of the specific gravity, a standard for each of these solutions; so that those who may have occasion to employ the nitrate, the acetate, or the muriate of barytes, will know how to procure a solution that will always contain the same proportion of barytic earth.

Not long after the peculiar properties and the decided characteristics of this earth became known, some chemists suspected that it was a metallic oxide, and the usual methods were resorted to for its reduction. That it is the oxide of a metal very difficult to be reduced, was the opinion of Bergman and Lavoisier; but it was reserved for Davy to demonstrate and establish the truth of this conjecture. The detail of the ingenious experiments by which this celebrated philosopher separated the metallic substance, which is the base of barytes, may be seen in the Philosophical Transactions, for 1810, page 63.

I cannot close this essay without

adding a few remarks on the uses to which this singular earth may be applied.

Hitherto it has chiefly been employed as a chemical test, and in the formation of certain barytic salts. It has also been used by a few scientific physicians, in certain diseases, with very good effect.

In the year 1784, Dr. Crawford made his first experiments on the powers of muriate of barytes on the animal economy; and in the year 1788 many trials were made of it in desperate cases admitted into St. Thomas's Hospital[37], and in a variety

[37] See a paper on the medicinal properties of the muriated barytes, by Dr. Adair Crawford,

of instances these attempts proved remarkably successful. The cases in which it was more particularly useful were those of painful tumours, cancer, and scrophula.

The ever to be lamented Pelletier, in his observations on strontian and barytes, remarks that "The success which Dr. Crawford met with in the internal use of muriate of barytes, in the treatment of scrophulous diseases, begins to be known in France [38], and several physicians

in vol. ii. of the Medical Communications, London, 1790, pages 301—360.

[38] It has been often said that there is a fashion in medicine; but it is surely a singular circumstance, that the English physicians, who were the first to employ barytes as a medicine,

already prescribe this new medicine[39]."

Considering the poisonous quality of this earth, I think it reasonable to infer, that if judiciously applied it may be extremely useful in some dangerous and otherwise incurable complaints[40]; though it may be ne-

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should nearly give up its use, when the French, who had been in the habit of giving muriate of lime for scrophulous diseases, began to use it; and that we in our turn should adopt the muriate of lime, which is now the common English medicine for such complaints, after the French had abandoned it.

[39] See Nicholson's Journal, 4to, vol. i. page 529.

[40] I am credibly informed that the muriate of barytes has been found to be a specific in some obstinate cases of worms, which had

cessary to institute numerous experiments before the nature of its effects on the animal economy be thoroughly understood and properly appreciated.

But in preparing the medicine, the utmost care should be taken to have it perfectly pure; for some specimens of the carbonate of barytes contain copper, and others arsenic. An attention should also be paid to the saturation of the acid; for it will be very difficult to obtain an uniformity in the doses, unless a saturated solution be always employed.

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resisted all the common formulæ; and that a quack medicine, which has been very justly celebrated for the cure of this complaint, has barytes for its base.

Dr. Crawford has, however, remarked, that if a saturated solution be administered, a *very small* quantity of muriatic acid should be previously added, to remove the bitter taste which is peculiar to this salt, and occasion it to sit pleasantly on the stomach. But no unskilful person should ever venture to administer barytes internally, in any form.

From the appearances which pure barytes presents when slaked, and especially from its ready solubility in water, one would suppose it to be useful in making hard and tenacious cements, particularly for important purposes. This I think was hinted by one of the French chemists several years ago; but I have never heard

of its having been employed in this way.

It may, however, be readily tried; for nothing can be easier than to prove the fact by sulphate of barytes, the common cauk of the Derbyshire mines. This, when ground small, and mixed with one third of its weight of pulverized charcoal, is only to be submitted to a red heat, to convert the acid to sulphur, and to be continued in that heat till the regenerated sulphur is completely burnt off. The earth that remains might then be preserved for use in close vessels.

For certain underground works, aqueducts, bridges, and for some other buildings of importance, this

earth, I conceive, might be highly valuable and useful. As a cement for porcelain and glass, I should think it would surpass every other preparation. Nevertheless, it must be remembered, that every thing would depend upon its being applied at the moment of its being mixt with the water.

But there is a purpose not yet named, and to which this peculiar substance might be applied, which would be of more importance, medicine excepted, than any other for which it can be used. I allude to the decomposition of common salt, and the separation of its alkali.

Whenever the carbonate of this earth shall be found among us in as

great plenty as its sulphate[41] (and I have not the least doubt but that this inestimable treasure is distributed in abundance in various parts of these islands) we shall have within ourselves ample means of preparing the mineral alkali, without applying to Spain and other places on the continent.

Wherever there is an establishment for the distillation of the pyrolig-

[41] If salt could be had duty free, the maker of alkalies might procure it at about 40*s.* per ton, and then if he could not get the carbonate of barytes, it might answer his purpose to employ the sulphate in its decomposition, though it would be necessary to convert the sulphate into a sulphuret, and then to separate the sulphur by another process, before the barytic earth would be fit for use.

neous acid, the manufacture of this alkali might be carried on to great advantage; for this acid would expel the carbonic acid from the barytes, and then by submitting it to a proper heat, the acetous acid would be burnt off, and the barytes would remain free and sufficiently pure for use [42].

If the barytic earth, thus prepared, be simply thrown into a solution of common salt, it will immediately occasion its decomposition, and muriate of barytes with caustic soda will be produced.

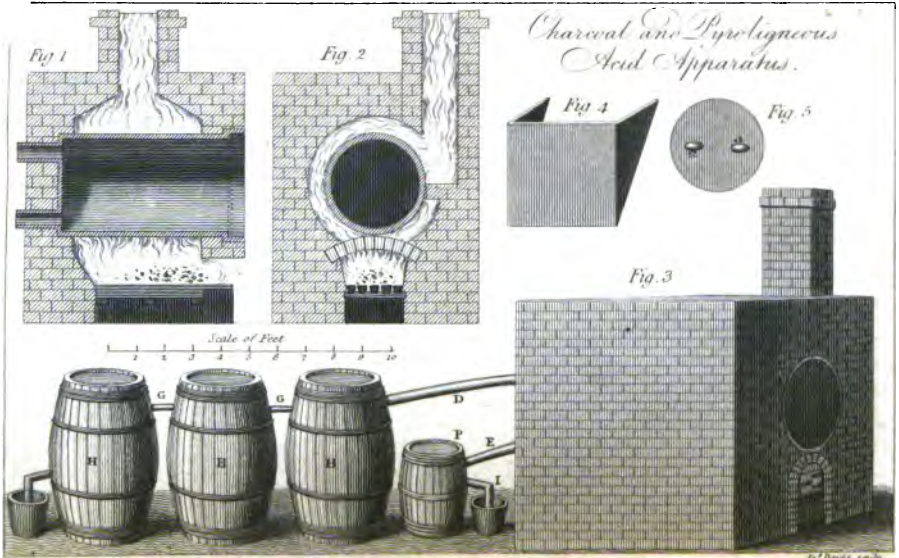
[42] The operator need be under no apprehension of losing any of the barytic earth by the intensity of the heat required for separating the acetic acid; barytes being neither volatile nor fusible at any heat that we can give it.

The abundance of pit-coal which is distributed in various places, together with our other peculiar advantages, have enabled this island, as a manufacturing country, hitherto to stand unrivalled: how much therefore is it to be regretted that two such invaluable treasures as our mines of rock salt and barytic earth should still continue locked up from an enterprising people, by a prohibitory, impolitic, and excessive impost!

ESSAY VI.

ON

CARBON.


Charcoal and Pyroligneous Acid Apparatus.
Fig 1
Fig. 2
Fig 4
Fig 5
Fig. 3
Scale of Feet
1 2 3 4 5 6 7 8 9 10
G
G
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ESSAY VI.

ON

CARBON.

CARBON is a name now universally adopted for charcoal, or rather for that pure part of its basis which, during combustion, combines with oxygen, and escapes in the form of carbonic acid or fixed air. Carbon is so abundant in nature that it occurs plentifully in the animal, the vegetable, and the mineral kingdoms; in combination with gas, with fluids, and with solids. It is found in the

bowels of the earth, in the mines of plumbago, anthracolite, jet, glance coal, and in every kind of pit coal, of which it forms the most material part. It is also separated from the lungs of all animals in the act of respiration; and it is the basis or skeleton of all vegetables, from the small anemone of the garden, to the huge oak of the forest.

Notwithstanding this abundant distribution of carbon, there is some doubt whether it has ever occurred perfectly pure in nature. The most pure state in which it has ever been seen is certainly that of the *diamond* [1],

[1] Fourcroy remarks, that "in many compounds, carbon, though very abundant, leaves them frequently a very brilliant white colour,

which, though commonly deemed to be one of the precious stones[2], and

like that of cotton, &c. The diamond is the more white and transparent the purer it is." System of Chem. Knowledge, vol. i. page 247. For some curious remarks on the black colour of charcoal, see Dr. Bancroft on the Philosophy of Permanent Colours, page 48, and Annales de Chimie, vol. v. page 80.

[2] Diamonds are sold by the carat, which is four grains. Unblemished diamonds, when polished, are worth about 6*l.* per carat. The mode of calculating their value is by squaring the number of carats which is the weight of the diamond, and then multiplying the amount by the agreed price of a single carat. Thus, those which are of an unusual size always cost immense sums. That at the court of Russia, which weighs 779 carats, would, upon this calculation, amount to upwards of three millions six hundred and forty thousand

classed with them, is now found to be nothing more than crystallized carbon, as far, however, as the most careful chemical analysis has yet been able to discover[3]. The precious stones are chiefly composed of one or more of the earths and metals; the diamond, on the contrary, contains nothing of the kind.

There is, however, a great difficulty attending this, for, it is evident

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pounds sterling. But the value of brilliants is often modified by their form, as has been very satisfactorily shown by Mr. Jeffries in his very lucid and ingenious treatise. See Jeffries on Diamonds and Pearls, 69 octavo pages, with 30 plates, price one guinea.

[3] Sir H. Davy has, however, lately asserted that the diamond contains a small portion of oxygen.

that it must have been dissolved in water in the bowels of the earth, or it would not have acquired that peculiar crystalline form in which we see it, and we cannot comprehend how it could be dissolved in that fluid; for, in our hands, water has no action whatever upon it[4], nor does it exert any solvent power on carbon, in any state in which we can submit it to its action.

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[4] The diamond is the hardest substance in nature, and hence there is no way of grinding or polishing diamonds but by acting upon them with their own powder, which is obtained by laborious rubbing of them one against another. If the diamond be exposed to the sun, it refracts and decomposes the rays of light more effectually than any other transparent body.

Carbon has neither taste nor smell; it is a bad conductor of heat; is altogether insoluble in water, and is perfectly infusible by the strongest fire that can be applied, provided it be defended completely from the access of atmospheric or any other air containing oxygen.

Rouelle the younger proposed indeed a problem in the Journal de Médecine for October 1762, which shows that he imagined he could dissolve vegetable coal in the palm of the hand[5]. How he could effect this I confess I have no idea, as none of the fluid menstrua with which we

[5] Other curious experiments by Rouelle may be seen in Mém. de l'Acad. Roy. de Paris, Année 1747, page 49, &c.

are acquainted have any action whatever, as solvents, upon carbon.

Strong nitrous acid, by peculiar management, may be made, we know, to inflame carbon, and when once thus inflamed it will burn with considerable brilliancy; but this arises from the decomposition of the acid, and is owing to the rapid combination of its oxygen with the charcoal, for which it has a powerful affinity.

In treating of carbon it is usual to adduce charcoal as a familiar instance of its existence, carbon being the basis of all charcoal. On this account it may be proper, in the first place, to speak of the methods for obtaining this article, and also of its peculiar properties.

Charcoal is too well known to require any minute description; but as every body may not be aware of its characteristic properties, it will be necessary to dwell more circumstantially upon them. The charcoal of wood is light and porous, so much so that it is possible to blow entirely through it. It is also very brittle, and easily reduced to a fine powder; it absorbs light very abundantly, which occasions its blackness; at a red heat, it decomposes water and reduces metallic oxides[6]; it absorbs

[6] Charcoal is so efficacious in reducing metallic oxides, that Mrs. Fulhame had no difficulty in producing the same effect, when she merely digested an alcoholic solution of potash on charcoal powder, and employed the

all the gases in abundance; it decomposes many of the acids by abstracting their oxygen; and it is one of the bases of the prussic acid and of a great many other compounds [7].

One of the most important of these combinations is in the article of gunpowder, which is generally made to contain about fifteen per cent. of charcoal. The usual proportions of its ingredients are 76 parts of well purified nitre, 9 of sulphur, and 15 of charcoal.

The first intimation that was given of gunpowder, was by that great

liquor which resulted from it. Fulhame on Combustion, 8vo, 1794, pages 126—134.

[7] From charcoal and nitrous acid Mr. Hatchett forms his artificial tannin.

philosopher Roger Bacon, in his treatise entitled, *De Nullitate Magiæ*, published at Oxford in 1316, nearly 150 years before the invention of printing, and about 22 years after the death of its venerable author. "You may," says he, "raise thunder and lightning at pleasure, by only taking sulphur, nitre, and charcoal[8], which singly have no effect, but, mixed together, and confined in a close place, cause a noise

[8] Bacon only mentions the sulphur and nitre in direct terms, and, as though he were fearful of imparting the dread secret, conceals the charcoal under an anagram. The words are, sed tamen salis petræ *lure mope can ubre*, et sulphuris, &c. The words which are printed in italics are an anagram of CARBONUM PULVERE, charcoal powder.

and explosion greater than that of a clap of thunder[9]."

Polydore Vergil relates, that gunpowder was invented by one Bartholdus Schwartz, a German chemist, who happening to triturate some sulphur, nitre, and charcoal in a mortar, was surprised and alarmed at an unexpected explosion, which blew off the head of his mortar to a considerable distance.

The probability is, that this was a *second* discovery of the same thing,

[9] The important discovery of gunpowder is thus recorded by a modern writer:

"This taught illustrious Bacon to explore
Metallic veins, and part the dross from ore;
With sylvan coal in whirling mills combine
The crystal'd nitre, and the sulphurous mine;
Through wiry nets the black diffusion strain,
And close an airy ocean in a grain."

and that he knew nothing of the disclosure which Bacon had made, and who was doubtless in possession of the secret 100 years before the time alluded to by this author.

It appears, however, that in the year 1380 this Schwartz instructed the Venetians in the use of gunpowder, and that all Italy complained of it, as a manifest innovation on the rules of warfare; although it is evident that this was not the first instance of the use of gunpowder in war; for it is related by Peter Mexia, that when "the Moors, in 1343, were besieged by Alphonsus XI. king of Castile, he discharged a sort of iron mortars upon them, which made a noise like thunder."

Similar effects, and even in a much higher degree, may be produced by the mixture of carbon with the hyper-oxymuriate of potash and sulphur; and for some purposes, this terrible compound is preferable to common gunpowder. Its explosive effects are truly astonishing [10].

"Pent in dark chambers of cylindric brass,
Slumbers in grim repose the sooty mass;
Lit by the brilliant spark, from grain to grain
Runs the quick fire along the kindling train;
On the pain'd ear-drum bursts the sudden crash,
Starts the red flame, and death pursues the flash.
Fear's feeble hand directs the fiery darts,
And strength and courage yield to chemic arts."

DARWIN.

[10] Some particulars respecting this new kind

Charcoal, when made on a large scale, is generally prepared in the following manner. A large quantity of billet-wood is piled in a heap; this is covered with turfs and sand to prevent the free access of atmospheric air, and then the heap is set fire to, at several holes near the bottom, which are always made for that purpose. At first a hole is left open at the top to occasion a draught, and produce a better and more regular combustion. After a time this orifice is covered with turf; and when it is perceived that the flame has pervaded every part of the heap, the holes at the

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of gunpowder, and which are not generally known, may be seen in the Additional Notes, No. LVI. of the Chemical Catechism.

bottom are closely stopped also. By this management the whole of the wood becomes ignited, though it is not burnt to ashes as it would be were a free circulation of air to be permitted; but, by closing the openings and leaving the fire smothered up, a heat is preserved sufficient to decompose and dissipate every thing of a fluid or gaseous nature in the wood, so as to leave the whole pile in a carbonized state. The mass is then allowed to cool sufficiently to be uncovered, and the billets, now converted into charcoal, to be removed.

This method of making charcoal is doubtless very ancient. Theophrastus Eresius, the successor of Aristotle, who lived more than 300

years before Christ, has described it very fully [11]. Pliny informs us that in his days the wood was formed into a pyramid, the apex of which was covered with clay [12]. There is, indeed, abundance of evidence that the ancients were acquainted with several of the properties of charcoal, and employed it for various purposes.

It has, however, been discovered within a few years, that charcoal can be much more perfectly prepared by a method different from that which

[11] This excellent philosopher, who wrote more than 200 different treatises, chiefly on subjects of natural history, lamented, at the age of 107 years, "That he was to die, just when he began to know how to live."

[12] Holland's Pliny, folio, London, 1601, book xvi. page 459.

has just been described, and which is now generally adopted for the preparation of that which is consumed in the manufacture of gunpowder.

In this process the wood, previously freed from the bark, is placed within large cast-iron cylinders, which are fixed horizontally in brick-work so as to be easily heated red-hot by fires placed beneath them.

These cylinders during the distillation have no communication with the external air, but at one opening, and this is destined to allow of the escape of the acid and the different gases; so that, when the operation is over, nothing remains in the cylinders but the charred wood, divested of all impurities.

In some manufactories the charcoal is drawn from the cylinders, while red-hot, into immensely large canisters, made with riveted plates of sheet-iron, and with moveable covers, which fit perfectly, so as to close them completely. In these it remains safely preserved from the action of the atmosphere till it is entirely cold. These canisters are so contrived, as to their number and size, as to contain the whole produce of one charge[13].

[13] The writer of this Essay would be culpable, were he not to caution his readers against adopting this mode of making charcoal, for the circumstance of removing it from the cylinders while red-hot must very much injure the health of the workmen so employed.

In some other manufactories the wood is not put into those cylinders fixed in the brick-work, but into others which are made of sheet-iron, and contrived so as to fit within the others. Here the cast-iron cylinders acquire a red-heat, as in the former case, and that heat is found to be sufficient to char the wood contained in the wrought-iron case.

When the operation is finished and the wood is found to be sufficiently charred, which is always known by the volatile parts having ceased to distil over, a block and tackle are affixed to the inner cylinders, which are drawn out in a moment, and others of the same dimensions, previously filled with raw

wood, are by the same means directly swung into their places. In this way the process goes on without interruption, and the proprietor is enabled to allow the charcoal to cool completely, before it is removed from the vessel in which it is prepared. In order to adhere strictly to this rule, it is of course requisite to have a number of the wrought-iron moveable cylinders in proportion to the extent of the work, so that while some are cooling others may be charged, and exposed in the fixed cast-iron apparatus [14], and thus no time will be fruitlessly expended.

[14] Drawings of the modern apparatus for the preparation of charcoal will be found in the plates, figures 13 and 14.

This method of working not only produces better charcoal[15], but it has the advantage of furnishing a large supply of an impure kind of vinegar, or acetous acid, which is very useful in several of our manufactories. This acid was formerly considered to be of a peculiar nature, and distinct from all others; it was named the *pyroligneous* acid, and in commerce it is still known by that appellation.

[15] It is remarkable that, although the charcoal prepared by this process is so superior for making gunpowder, it is not well calculated for some other processes. It is not of half the specific gravity of the charcoal which is made out of doors in the common way, and covered up with turf. The makers of iron particularly, will not buy it.

When this acid is suffered to stand a few weeks undisturbed, it deposits a peculiar kind of tar, and this in considerable quantity [16]. For some years past this tar has been a great burden on the hands of those who have been largely concerned in this trade. For, though it has been employed in a great variety of ways, the consumption has never kept pace with the quantity produced, and with-

[16] Every kind of wood will produce this acid and tar, when treated by what is called the destructive distillation. Peat also will yield it in abundance. A friend of mine distilled some which was dug in Wholmer Forest, and procured pyroligneous acid from it. When this acid was redistilled, it left a residuum of tar, similar to that which is produced from the second distillation of wood acid.

in my own knowledge many tons of it have been buried in the earth, merely to get rid of it.

It was tried in one of the public dock-yards; but the quantity produced at that time in Great Britain was, in comparison with the quantity of pitch and tar required for the royal navy, too insignificant to permit the idea to be ever entertained of its being generally used in the Government dock-yards; particularly as it will not combine with the imported pitch and tar in common use.

I have myself, in various ways, made experiments upon this tar, and notwithstanding this I am so convinced of its value, that I am desirous of placing the question before the attention of the public.

For every kind of wood fence, it is the best preservative of any thing that can be applied. It should be gently heated in an iron pot, and put on with a brush. When first put on, it gets so completely into the wood, that many who have tried it have supposed that it could be of little use. It soaks in, and seems to leave no *body*, as the artists express it: but if the work thus treated be examined after it has been exposed for some days to the sun, its surface and the texture of the wood will evidently be much altered; for it will now be found so impervious and hard, that it will be very difficult to make any impression upon it.

If a second, and especially if a third coat of this tar be put upon

wood, it will then bear out, as the painters call it, sufficiently well; and I have reason to believe that it will preserve all outside wood-work much more effectually than it can be by any other expedient that has hitherto been contrived for this very important purpose.

For ornamental paling, and indeed for all good outside work, a first, or perhaps a first and second coat of this tar might be used with great advantage; and when these shall be completely dry, the work might be finished with white lead and oil, as usual.

Besides the extreme hardness which this article imparts to wood, it has also the advantage of effectually preserving it from worms and from all

other insects. Even where wood has become worm-eaten, I have observed that this tar will stop the progress of the decay; and I am inclined to think, from what I have seen, that a paling of worm-eaten deal, if it be not absolutely rotten, will last longer when covered with this article, than a similar fence made with new deal without such treatment[17].

To those persons to whom a little additional expense would be no object of consideration, the following preparations are recommended. They will be found to improve the appear-

[17] It may be necessary to remark, that the article here spoken of is very different from the tar which is distilled from mineral coal, and was recommended by the Earl of Dundonald, thirty years ago, for a similar purpose.

ance of the application very considerably:

1 Gallon of the tar,
1 Oz. tallow,
2 Oz. pulverized rosin, melted together and put on warm; or

1 Gallon of the tar and
2 Oz. of pulverized sulphate of iron to be used in the same manner as the foregoing mixture.

The first of these prescriptions looks the best, but the latter has been proved, and has lasted good for twenty years. How much longer it would be an effectual preservative for the wood, time only can discover.

At different times I have made many other trials of the tar from pyroligneous acid, and I find it useful as a varnish for a variety of goods made of rolled iron, or of cast iron.

A more beautiful varnish for these purposes may be prepared by the following process:

1 Gallon of the wood tar,
½ Pint of rectified spirits of wine,
intimately mixed by a gentle heat.

If this be laid on hot and properly hardened, it will prove a beautiful and durable black varnish.

As the peculiar properties of such a refuse article are not likely to be generally known, I think it a duty I owe to my country to give as much publicity to these facts as possible, by withholding no information respecting them which it is in my power to impart; particularly as the engagement which I entered into, some years ago, to take all the pyroligneous acid which should be produced

at the King's cylinder works at Farnhurst in Sussex, amounting to many thousand gallons annually, gave me an opportunity of making many and reiterated experiments on this singular and important residuum.

Some time ago a very remarkable circumstance respecting the preparation of charcoal came to my knowledge, which I think worth recording, as it may preserve some individuals from great loss and disappointment, and must be of considerable importance to us as a nation.

A gentleman of opulence, residing near the metropolis, who is the proprietor of some large gunpowder works, and who prepares his own charcoal for that manufactory, sus-

tained a considerable pecuniary loss from the following occurrence.

He had for some time been collecting a portion of the pyroligneous acid, which arises from the wood in the act of charring; when a certain chemical adventurer persuaded him to make an alteration in the apparatus, with the view of procuring, as it was pretended, more than double the quantity of acid.

According to this advice, he put up at a considerable expense an entirely new apparatus, which was so constructed that the pipes which conveyed the acid, as it arose from the ignited wood, passed through a large body of water, which so completely cooled it, that the whole of it was

condensed and collected in the recipient. In the last pipe, exactly at the place where it emerged from the water, there was a small hole, to prevent any part of the apparatus from bursting. Whenever the cylinders had done working, it was directed that this hole should be firmly stopped, and that then the whole apparatus should be suffered to cool.

By this arrangement a much larger quantity of acid was preserved, as the adviser had predicted, and which promised an ample repayment of the expense of the alteration: but it was quickly perceived that the gunpowder was very much deteriorated; and this happening at a time when the house had a contract with Govern-

ment (in which case the gunpowder is always accurately proved) several parcels were complained of, and one large delivery was actually returned as unfit for the public service.

These complaints were not only unexpected, but peculiarly mortifying, because the manufacturer had been pleasing himself with the idea that the gunpowder would be improved, and he could not at all account for the cause of this unfortunate change in the quality of his article.

At first he suspected that the nitre might contain some deliquescent salts; but even when he had made his powder from the nitre which had been refined at His Majesty's works, where the utmost care is taken in the process,

the powder was still the same. Then the sulphur was examined; and when nothing amiss could be discovered there, he began, for the first time, to suspect that the fault must be in the charcoal, although that which they were then using was in appearance finer and handsomer than any they had ever had.

The proprietor was now, however, convinced that the alteration in the quality of the powder could not possibly be otherwise accounted for than by attributing it to this alteration in his apparatus: he therefore instantly ordered the whole to be removed, and reverted to his old plan of distillation, by which one third, at least, of the acid is dissipated in gas, and

entirely lost. But the consequence was evidently favourable, and the error fully detected. The gunpowder manufactured since is as good as it had formerly been, and he has received no more complaints.

This circumstance was not mentioned to me till after the new apparatus was destroyed, or I certainly would have advised the proprietor to continue the new arrangement, and to make no other alteration than merely to provide the means for the incondensable gaseous products to be properly dissipated. For, by stopping up the venthole, the latter portions of the incondensable gas could not get away; and every chemist knows the property which charcoal

has of absorbing with avidity all the gases, particularly this, and in considerable quantity. If, instead of stopping up the venthole, several others had been opened during the last stage of the process, and suffered to remain so while the cylinders were cooling, I doubt not but this charcoal would have turned out equal in goodness to the former.

The kinds of wood which are preferred for this business are the dog-wood, the alder, and the willow; and since these woods [18] have been made

[18] Within these twenty years very large plantations of dog-wood and alder have been made in the counties of Kent, Sussex, and Surrey, so that at this time His Majesty's and other private manufactories of gunpowder are entirely sup-

use of, and the last-mentioned process has been employed for making the charcoal, any given quantity of the British gunpowder will drive a ball one third further than the powder prepared with ordinary charcoal.

This may in some measure be owing to the charcoal of these woods taking fire much quicker; for we know how much sooner the coal of some linen, when used as tinder, will take fire, than that of others, and how readily that kind of fungus burns which is called German tinder [19], a

plied with charcoal from wood of the above descriptions.

[19] To render this fungus still more combustible, the Germans purify it by boiling it in an alkaline lye. They then dry it, and boil it again in a solution of saltpetre. Therefore

species of agaricus, known to botanists by the name of boletus igniarius. The slightest spark communicated to this tinder will be sufficient to occasion a commencement of combustion.

The Government of France has for some time been aware of the importance of attending to the preparation of charcoal for public use. The old method was discontinued several years ago, and it has since been made in large trenches cut within the ground, and lined with brick, the makers of it conceiving that by this management the same kinds of woods will produce lighter

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the tinder sold in the shops is not the simple female agaric, but a compound of that vegetable production and nitre.

and softer charcoal than when burned in large piles in the open air[20].

For philosophical experiments charcoal may be readily made by filling a large crucible with short pieces of wood, covering these with sand, and submitting the whole to a red-heat in a common fire-place. When I have had occasion to melt a block of tin, preparatory to making the nitrate or muriate of that metal, I have sometimes prepared very excellent charcoal by immersing pieces of wood in the melted metal, and holding them beneath the surface till the whole was charred entirely through.

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[20] See Chaptal's Chemistry applied to the Arts, vol. ii. page 288.

When this method is adopted, the charcoal may be plunged either into water or a bed of sand, the moment it is drawn from the melting-pot, according to the purposes for which it may be wanted; and it will be found that by either of these modes it will be entirely preserved from the action of the atmosphere.

Whenever pieces of wood or other vegetable matters are charred without being disturbed during the operation, the grain of the wood and the form of the filaments are always preserved distinct and entire. If we examine writing paper or linen which has been covered up and burnt without the free access of atmospheric air, the wire marks of the

paper and the threads of the linen will still be seen with distinctness[21]. We read indeed of some who have been so dexterous as to char an arrow without altering the form even of the feather[22].

On the contrary, if wood be burnt in the open air, the greatest part of it will be dissipated in gas. Common oak, if charred in a proper manner, will lose only from two

[21] When Sir William Hamilton explored the ruins of Herculaneum, he found corn that was converted to charcoal by the eruption of Vesuvius in the year 79 of the Christian era, and which was so well preserved that the grains of wheat were easily distinguishable from those of the rye.

[22] Neumann's Chemistry, by Lewis, vol. ii. page 277.

thirds to seven tenths of its weight; whereas if the same kind of wood be burnt in an open fire-place, the residuum of the combustion will not be more than about one 200dth or one 250th of the original weight of the wood employed [23].

Caspar Neumann, who made many experiments on charcoal, informs us that for the reduction of the metallic

[23] This, however, will vary according to the different ways in which wood may be burnt, and it accounts for the different statements which have been given of these results. Dr. Watson says that he procured 22 grains of charcoal from 96 of dry oak. Van Helmont, that 62lb. of the charcoal of oak will produce 1lb. of white ashes, whereas Sage says that 100lb. of charcoal will not give more than 2oz. of ashes.

oxides, the charcoal of the heavier woods, as that of the oak and the beech, is preferable; and that, for common fuel, such charcoal gives the greatest heat, and requires the most plentiful supply of air to keep it burning; while those of the lighter woods preserve a glowing heat with a much less draught of air; and that for purposes where it is desirable to have a steady and a still fire, charcoal should be employed which has been made from wood previously divested of its bark, since it is the cortical part which crackles and flies off in sparks during combustion, which the coal of the wood itself seldom does [24].

[24] Neumann's Chemistry, vol. ii. page 277.

For making crayons of charcoal, the willow is the best wood that can be employed, as the softness is in all its parts quite uniform. The coals of the hard woods, such as box and guaiacum, are considerably harder than others, while the charcoal of the kernels of fruits is quite soft and friable[25]. But as a pigment the coal of ivory is the most intensely black and the most beautiful. I speak here, not of the common ivory-black of the shops, but of the charcoal which is prepared by burning real ivory in closed vessels[26]. As a powder for

[25] See Lewis's Commer. Tech. page 337; also Dr. Grew on the Anatomy of Plants.

[26] The perfect durability of carbon as a pigment, may be seen in several of our old

cleaning the teeth, the best charcoal is that made from the shell of the cocoa nut.

A friend of mine, who is engaged in refining rancid fish oil by means of tannin, has fitted up an apparatus for burning the gelatinous or leather kind of precipitate which results

churchyards, where the letters made with lamp-black are still perfect, though the white lead with which the body of the stones was painted is entirely destroyed. Some few years ago I remember to have noticed this circumstance on Sir Hans Sloane's monument in the churchyard of Chelsea. But this property of carbon is shown in a more striking manner by the writings which were found in the ruins of Herculaneum, which have retained their original blackness for two thousand years. The ancients wrote with ink made from ground charcoal.

from his operation, and which is of little value for any other purpose. This charred powder, or soot, he informs me, proves to be a finer and better black than any he can procure by other methods.

The article known in commerce by the name of lamp-black, is carbon in the state of a light impalpable powder, and is procured by burning the refuse of pitch in peculiar furnaces, with long flues terminating in a close chamber, the ceiling of which is covered with porous cloth, through which the gas that is disengaged in the process may escape and the soot be left behind[27]. The coal

[27] A very particular account of this process

of all resinous substances is of a similar nature.

Some artists, for very nice purposes, have collected the carbonaceous matter which arises from a lamp in burning the vegetable oils, by suspending some convenient substance at a proper distance over the flame.

The beautiful brown pigment called *bistre* is prepared from an aqueous infusion of wood-soot. Some account of its preparation is related by Lewis in his "Commerce of the Arts," but more ample directions for

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may be seen in Hobson's Weigleb, 4to, p. 540. A process somewhat different from this is described in the Stockholm Transactions for the year 1754.

making it are given in the French Encyclopedia.

If it be required to purify any carbonaceous matter to render it fitter for a pigment or other nice purpose, it may be done by first well calcining it in a close vessel, and then lixiviating it in water slightly acidulated by nitrous acid. This will separate the earthy or metallic particles with which it may be contaminated; and by making it a second time undergo in the same way the action of a very brisk fire, we obtain a charcoal very near to the state of pure carbon[28].

A charcoal will be produced from

[28] I am indebted to Chaptal for this idea.

animal substances burnt in closed vessels, but this differs from vegetable coal in some particulars. It is always more dense; and if it be made in a glass or earthen vessel, it adheres to it more than the carbon of vegetables; it is also less combustible, and contains more foreign matter.

It may be ascertained whether any carbonaceous matter be produced from animal or from vegetable substances, by the following trial. A vegetable coal will burn on a red-hot iron, into white ashes, and these will be readily dissoluble by sulphuric acid into a bitterish liquor, whilst the ashes of animal substances

are very sparingly affected by that acid, and form with it a compound having quite a different taste[29].

Charcoal is endowed with many singular properties which cannot be too generally known, as some of them qualify it for rendering very important services to the arts. It has been mentioned before that it is a bad conductor of heat; but I cannot avoid remarking that few persons, comparatively speaking, have availed themselves of this property, although there are innumerable instances in which it might be employed with great advantage. The mention of a few of the most important of these,

[29] Lewis's Commercium Philosophico-Technicum, 4to, 1763, page 377.

must however suffice on the present occasion.

One of the most beneficial applications of charcoal, as a slow conductor of caloric, would be in some processes where it is necessary, for any given time, to preserve an equable temperature.

Thus, all those vessels which are heated by steam, if they were made double, and the space between the outer and the inner vessel filled with ground charcoal, the heat would be so prevented from escaping[30], that any one particular temperature might be kept up for a great length of time,

[30] Ground charcoal will conduct heat more slowly than even dry sand. Guyton has shown that this is in the proportion of 3 to 2.

and a material saving in the article of fuel would accrue by adopting such a plan.

In extracting the colouring matter of dye-woods, and in making some other colours for the use of calico-printers, it is of great consequence to heat the vessels by steam; for by this mode of preparing decoctions the workmen are prevented from ever giving the materials a greater heat than that of 212°.—and the injury which was formerly done by the grosser matters burning at the bottom and sides of the copper, is avoided. Several manufacturers have now adopted this method, and I have lately seen some apparatus in two or three places which are constructed

on this principle, and that appeared to me to be complete in every respect, excepting that they suffered much of the caloric to escape; all of which might have been saved, and turned to a good account, by employing the powdered charcoal in the way I have just described.

Again, whenever churches or other large buildings are to be warmed by steam, so much of the conducting pipes as are not actually within the buildings should always be surrounded in this manner: then, no part of the heat could escape till it had been delivered within the space destined to be warmed by it.

In like manner, in the manufactories of starch, paper, gunpowder,

Prussian blue, and a variety of other articles that might be mentioned, every part of the apparatus for drying these by steam, and which is not actually within the drying-rooms, ought to be secured in the same way.

The common steam-cooking apparatus and other culinary utensils would be much improved were they fitted with double covers, and the inner spaces between these covers filled up with carbonaceous matter.

Moreover, by securing the conducting pipes in this manner, buildings might be effectually warmed and processes conducted, at any distance from the site of the boiler, as "steam is the most faithful carrier

of heat that can possibly be;" for it cannot deposit it on any bodies that have already acquired the temperature of 212°.

Owing to this non-conducting property of charcoal it is that it is very commonly employed in France[31] to coat furnaces, and to confine the heat, for which its incombustible nature fits it in a peculiar manner, it being the most refractory body we know of, provided it be excluded from oxygen.

In domestic economy, charcoal is invaluable. As a preserver of meat, it surpasses anything we know of. Game, or any kind of animal food

[31] Fourcroy, vol. i. page 248.

that has been over-kept, will be rendered perfectly sweet and wholesome by covering it with a few pieces of fresh burnt charcoal. Or, if it be far gone, boiling it for some minutes in water with a few ounces of such charcoal will effectually purify it[32].

By its means also molasses or treacle may be deprived of its disagreeable taste, so that it might be used in families instead of sugar. M. Cadet

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[32] That water impregnated with carbonic acid gas is such an effectual preserver of meat, is probably altogether owing to the carbon of which this acid gas is composed. An interesting letter from Sir William Lee, Bart. to Doctor Priestley on this subject, will be found in the Appendix to the fourth volume of the Doctor's Observations on Air.

Devaux says that he diluted twenty-four pounds of treacle with the same weight of water, and boiled it for half an hour with six pounds of pulverized charcoal, which entirely deprived it of its empyreumatic taste and smell. He then strained the saccharine liquid from the charcoal; and, having evaporated it to a due consistence by a gentle heat, found its flavour equal to that of good sugar[33].

The principle of refining sugar by means of charcoal is indeed the basis of the patent lately taken out

[33] Those who have occasion to use honey, and yet have an objection to its peculiar flavour, may deprive it of this taste by a similar management.

by Mons. Cronstat, and for which he required of the joint body of sugar-bakers in London a remuneration of fifty thousand pounds: and I have reason to think that the proprietors of a small concern lately established in the metropolis, where double loaves are manufactured of a finer quality than are produced at any other house, effect the purpose by the same means.

In like manner the disagreeable empyreumatic flavour which some brandies acquire in distillation, may be removed by digesting them on charcoal; and common malt-vinegar, if boiled on charcoal, becomes quite colourless like distilled vinegar, without being impaired in strength;

whereas it always becomes much weaker by the process of distillation.

On the same principle charcoal is frequently employed by the manufacturing chemist in purifying any of the salts which may have become coloured from accidental circumstances, or from their combination with heterogeneous matters. It is only necessary to redissolve them, and boil their solutions on charcoal, and when re-crystallized they will be found pure and colourless.

Even the common salt of hartshorn, (carbonate of ammonia,) which is prepared from a liquor distilled from bones, and which often requires great labour to render it of

the desired purity, loses the whole of its fœtid smell by being sublimed in conjunction with charcoal powder.

On long voyages the water, which has been laid in for the ship's crew, generally acquires a disagreeable taste and smell from standing so long in the wooden casks; but whenever this happens, it can be entirely purified by filtrating it through ground charcoal. It is always best, however, to send out water in casks that are charred within side, as water kept in such casks is always sweet. In London and elsewhere, it is very common to pitch water-casks on the whole of their inner surface; but surely it would be cheaper, and much more effectual for making them into

good water-casks, to light a fire of wood-shavings within them, and keep it burning till the whole of the surface on the inside is completely charred.

It is difficult to understand how charcoal acts, so as to purify so many vegetable and animal substances, and to remove the colour and the noxious taste and smell of such a variety of articles, and in such a variety of states and cases: but as charcoal has the property of absorbing all the known gases, and condensing them in its pores[34] in quan-

[34] Some interesting disquisitions on this subject may be seen in the Journal de Physique for 1783; in the Annales de Chimie, tome xxxii. and in Murray's Chemistry, second edition, vol. ii. page 486.

tities far exceeding its own bulk[35], to this probably the effect is entirely due.

That these processes may always answer, it is necessary that the charcoal should be fresh made, or that it should be heated red-hot under a cover of sand immediately before it is used, and that in nice operations the necessary quantity should be ascertained by previous experiment; for, if too much be employed, the articles on which it is intended to operate will sometimes be decomposed, especially if heat be applied; and if a sufficient quantity be not

[35] Morozzo's experiments on the quantity of the different gases absorbed by charcoal, may be seen in the Journal de Physique, An 12.

taken, the effect will be produced only partially. Mr. Lowitz, who has pursued this subject as far as any one, has given some very important directions, which are necessary to be attended to by those who employ this carbonaceous substance as an article of purification in any manufacturing processes[36].

In some cases it is necessary to use it in a pulverized state; but in all these instances, it should be pounded immediately from the fire, before it is exposed to the air; and what is not used should be preserved in glass bottles closely stopped, on account of the property it has of absorbing

[36] These directions will be found in Crell's Chemical Journal, vol. ii. page 270.

water and the gases in such abundance.

Mr. Chaptal has shown, that it absorbs 15 or 20 per cent. of water from the atmosphere, while cooling, and that soft coke acquires 25 per cent. of water in the same time[37].

Besides those which have been already mentioned, charcoal has many other uses in the arts. On account of its powerful affinity for oxygen, it is employed by the makers of glass and by soap-boilers and others, in decomposing many of the neutral salts called sulphats, so as to enable them to use their alkaline bases in the room of barilla and potash. More

[37] Chaptal's Elements, vol. iii. page 199.

of this, however, will be found in the Essays on the fixed alkalies and on glass.

Charcoal is employed also by the makers of *coloured* glass to communicate some peculiar tints of brown and yellow to their artificial gems. The amiable and ingenious Mr. Samuel Moore, who was many years the Secretary to the Society for the Promotion of Arts, Manufactures and Commerce, made an extensive series of experiments on this subject. Some account of his processes may be seen in the "Commercium Technicum," published by his friend Dr. Lewis[38].

On the Continent, it is a common

[38] Quarto, London, 1763, page 628, &c.

practice to char one end of all the posts or other timbers which are to be fixed within the ground; and if this be carefully and properly done, and so much of the timber be charred as is to be covered with the soil, it will be rendered imperishable, or at least it will last much longer than the parts above the ground which have not been charred. Indeed charcoal is perfectly incorruptible if buried in the earth; therefore the deeper the surface of the wood is charred, provided enough be left to give sufficient strength to such posts, the more effectually will they be preserved.

This method of charring timber is already practised in some parts of

England; and being convinced of the economy and efficacy of the practice, I mention it here in the hope of rendering it more general. All that is necessary is to light a fire upon the ground, which shall be surrounded with a wall built with loose bricks or stones, and then, when the pieces of timber are laid across the walls, to turn them round carefully so as to present every part to the action of the fire in succession; and when the whole surface to the depth of three quarters of an inch or an inch is converted to charcoal they will be sufficiently prepared. While burning, they should have a temporary covering of boughs or other fuel to preserve them from the action of the atmosphere, which

would be apt to convert part of the wood into ashes.

The incorruptibility of charcoal was well known to the ancients, and they availed themselves of this property on all important occasions. Of this we have abundant evidence.

In making the foundation for the temple of Diana at Ephesus it was necessary to drive piles; and when some of these were taken up of late years it was found that they had been charred before they were put down. Again, it has been stated that "about fifty years ago a quantity of oak stakes were found in the bed of the Thames, in the very spot where Tacitus says that the Britons fixed a.

vast number of such stakes, to prevent the passage of Julius Cæsar and his army. These stakes were charred to a considerable depth, had retained their form completely, and were firm at the heart."

That it is actually possible to render wood indestructible, will appear from the recollection of the process of nature usually called petrifaction. About sixty years ago, one of the timbers that supported the bridge which the emperor Trajan threw over the Danube a little below Belgrade, was taken up, and the outer part to the depth of half an inch was found to be converted to an agate, the inner parts were slightly petri-

fied, and the central were still perfect wood, though this timber had been in the water 1700 years[39].

In the Emperor's collection of minerals at Vienna there are many pieces of wood converted more or less into agates of various colours. Among them there are billets of half a foot or a foot in diameter thus petrified, and capable of taking a very fine polish. One of these is agate at one end, and retains its ligneous nature at the other.

In the History of the Academy of Sciences at Paris for the year 1763, is an account of Mr. Moll's cabinet of minerals, which is very effectual

[39] Kirwan's Geological Essays.

towards the conviction of those who deny the possibility of wood being thus petrified. The comparison which this eminent collector has made between certain woods and plants said to be petrified, and the same kinds of bodies in their natural state, seems to put this matter out of dispute.

Having made a large collection of wood that was turned into agate, he sawed off the thinnest laminæ possible from many of the pieces, and after polishing them, he examined them by the microscope, and perceived plainly the difference of texture in the different specimens. It was observable that one of these was doubtless fir, another reed, or some aquatic plant of that class; and on

examining shavings or small pieces of the wood to which he supposed the specimens belonged, it was impossible to resist the evidence furnished by this comparison. In both sets of objects the same direction of the longitudinal and transverse fibres of the wood is perceived, and the same arrangement of the vesicles [40].

In returning from this digression, it may be remarked that it were much to be wished that the English builders would adopt the practice above mentioned, and char every piece of wood before it is placed within the ground. Several years ago Dr. Watson sug-

[40] More on this subject may be seen in the Appendix to the Monthly Review, vol. xxxvi. page 557.

gested the propriety of charring all the wood used in mines and subterraneous drains, and particularly that employed in the covering of soughs, through which there is a current of water, and which rot in a few years by the alternate change of wet and dry[41]. I would remark, in addition, that if this had been the general practice, many sad accidents which happen from the breaking of such timbers would have been prevented, and some lives saved.

In connection with this subject it may be worth mentioning, "that when old chesnut, or other trees, are rotted within the trunk, and

[41] Watson's Chemical Essays, London, 1789, vol. iii. page 48.

threatened with speedy destruction by the progress of the carious taint, it may be stopped by applying fire to the decayed part, so as to char the whole of the neighbouring surfaces[42]." By this management the life of a favourite tree may often be preserved.

In enumerating many of the uses of charcoal, I have hitherto omitted to mention its employment in the manufacture of bar-iron, to the perfection of which wood charcoal is, I believe, essential. Formerly, all the wrought iron that was made in this country was manufactured with charcoal; but as the wood became scarce,

[42] See Chaptal's Chemistry applied to the Arts.

and the government restricted its use, the iron-masters gradually introduced the use of cinders and coke, and now most of the bar-iron which is made in these kingdoms is prepared chiefly by the latter methods. This, however, has reduced the quality of the English iron so much, that, for many purposes, the workers in this metal are under the necessity of employing Russian and Swedish iron, which is all prepared by means of the coal of wood [48].

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[48] Mons. Hassenfratz is of opinion that the superiority of the iron which is made with charcoal, is owing to its combining with a portion of *potassium*; and when it is considered how great is the difference between iron and steel, and how small is the quantity of carbon

The ores of iron are very abundant in this country, and for some hundred years had been worked to a great extent for the production of this metal; and as nothing was at first used for the reduction of these ores but wood-charcoal, the consumption of wood became so enormous that the legislature thought it advisable to interfere, and prevent its indiscriminate use.

By the act of the 1st of Queen Elizabeth, chap. 15, it is enacted, that no oak, beech, or ash timber, of

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that produces this difference, it may easily be believed that the potassium of the wood is capable of effecting the change in question. See Nicholson's Journal, xxv. page 51.

the breadth of one foot square at the stub, shall be cut down to be converted to charcoal for making of iron, in any part of the kingdoms of England and Wales, except in the county of Sussex, in the weild of Kent, and in certain parishes therein named in the county of Surry.

Notwithstanding this enactment, the makers of iron gave up the use of charcoal with great reluctance, as they imagined that it was impossible to make useful malleable iron without charcoal.

However, about the middle of the last century some few iron-masters got into the way of making bar-iron with the coke of pit-coal, prepared

from a particular sort of coal, and in a manner which was kept secret from the generality of the trade.

In the year 1773 Mr. Henry Horne published his "Essays on Iron and Steel[44]," with directions for reducing the common iron ore into pig-iron, and then into bar-iron, fit for the most curious purposes; and in the same work he gave directions for a more perfect method than any before known, of charring pit-coal, so as to render it a proper succedaneum for wood-charcoal in the manufacture of iron.

[44] Cadell, 12mo, 1773. This little volume is now become scarce: it contains, however, many interesting particulars, and is, I think, worth the perusal of those who are engaged either in making iron or steel.

Since that period the coke of pit-coal has been brought into more general use, so that, at this day, many thousand tons of coal are annually converted into coke, not only for the purpose of making iron, but for various other employments connected with the trade and manufactures of the country.

The coke of pit-coal is used largely in the drying of malt, &c.; in the fires of a variety of artists, to whom the smoke of pit-coal would be injurious; in refining gold and silver; and in the smelting of metals. In the preparation of this coke, the fuliginous, bituminous, and sulphureous parts of the coal, which would give a taint to the one and a brittle-

Coke Oven

Fig. 1

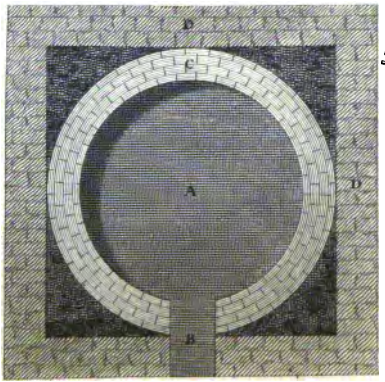


Fig. 3

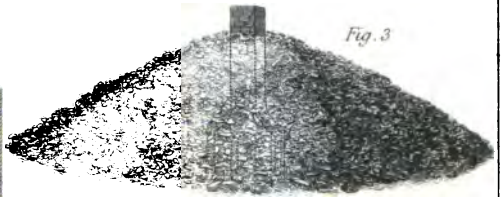
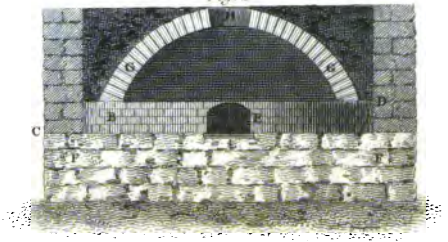


Fig. 2



Scale of Feet

ness to the other, are dissipated, whilst the more pure and carbonaceous matter is left[45].

The consumption of coke is now so considerable, that within these few years great attention has been paid to the selection of the best kind of pit-coal for its preparation, and to the improvement of the ovens in which the operation is performed. Those in the neighbourhood of Sheffield, belonging to the duke of Norfolk, are the best which I have seen[46].

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[45] See Lewis's translation of Neumann, vol. ii. page 277.

[46] A very particular description of these ovens will be found in the Additional Notes to the Chemical Catechism, No. 50. 6th edit.

It has been usual in the large iron-works to prepare the coke without ovens, merely by making large piles of common coals in the open air, somewhat similar to that mode of making wood-charcoal described at page 264, and setting fire to these heaps at different places at the same time; and when the mass appears to be thoroughly lighted, then to cover or smother up, as it is called, the whole heap with dust. In this state the combustion is continued till all the coal is converted into coke.

A new method of making coke has, however, lately been adopted at

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See also the plates to the present volumes, figure 15.

an extensive iron-work in the neighbourhood of Chesterfield, which has been found very advantageous.

For this purpose a substantial brick-chimney is built on an open space of ground, and the coal is piled round it. When the pile is constructed, instead of lighting it in different places on the outside of the heap, a quantity of ignited coal is thrown down this brick-chimney; which being built upon arches, the fire readily communicates through them to those parts of the pile which are immediately contiguous to the chimney, so that the fire commences in the *middle* instead of at the *outside* of the heap, and soon spreads through the whole mass. When sufficiently

burnt, and partially cooled, the heap is broken into, and the whole is then quenched by water.

The coke thus prepared is so much better than that which is produced in the common way, that a much less quantity is sufficient for making any specific quantity of iron.

This enables the blast furnace to hold an additional charge of iron-stone, and consequently the manufacturer can run considerably more pig-iron at every operation. The annual saving which this has occasioned is, I understand, far exceeding that which the proprietors themselves had expected; for, the quantity of the coke produced is much greater from a given measure of the

coals, and, what is of still greater importance, the iron is of a much better quality.

The proprietors of these works, who deem this new method of coke-ing to be a most important improvement in their manufactory, consider the cause to be totally inexplicable.

To hazard a conjecture, respecting the nature of this obvious improvement, I should certainly attribute all these advantages to the chimney, which from the nature of its construction occasions a constant draught of air through the whole body of the burning materials, and carries off all the gaseous products which would otherwise be absorbed by the coke, and impair its quality; similar

to the injury which the wood-charcoal received by stopping up the ventholes, as related at pages 279—285 of this Volume.

Before I conclude this Essay, it will be necessary to offer a few remarks on some of the varieties of mineral coal, in all of which the basis is carbon.

Mineralogists in their classification of coals have divided the whole into four species, very distinct from each other; viz. plumbago, or the *graphite* of Werner, which is a carburet of iron; the *anthracite* of Haüy, or, as it is more commonly called, *anthracolite*; jet, and cannel coal; and all the varieties of common pit-coal.

Plumbago, usually known by the very improper name of black lead, occurs in some particular spots in most countries in the world. It is well known as the article of which pencils are made[47], and is found in various situations, such as in the midst of mountains, in beds of quartz, and in masses of calcareous earth. It generally occurs in kidney-form lumps of various sizes from the big-

[47] From a remark of Sir John Pettus, I imagine black lead pencils have not been in use more than 150 or 160 years. "Of *late*," says he, speaking of black lead, "it is curiously formed into cases of deal, or cedar, and so sold as dry pencils, something more useful than pen and ink." Sir John Pettus's Fleta Minor, folio, London, 1686, article *Lead*.

ness of a pea to pieces of some considerable weight. Its specific gravity is about twice that of water. When pure, it consists of nearly nine parts carbon[48] to one of iron. Hence, as might be expected, it is as incombustible and indestructible as charcoal, unless heated with atmospheric air[49]. But some kinds of plumbago are very impure. Vauquelin has given the analysis of a French specimen which contained only 23 per

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[48] According to Sir Humphry Davy, the carbon of this mineral exists in the purest form.

[49] It is this property which renders plumbago one of the best substances in nature for the fabrication of those crucibles which are designed to resist the most intense heat.

cent. of carbon, 2 of iron, 38 of silex, and 37 of alumine.

To the modern methods of analysis we are entirely indebted for a knowledge of the nature of this substance[50]. Camden, our celebrated historian, calls it "a metallic earth, or hard glittering stone, used by painters to draw with. Whether," says he, "it be *pnigitis*, or *melanteria* of Dioscorides, or ochre burnt black by the heat of the earth, I cannot determine[51]."

[50] The ingenious Scheele was the first person who pointed out the nature of this mineral. He showed that by burning it in a peculiar manner it might all be converted into carbonic acid gas, except a small residuum, which he found to be iron. Scheele's Chemical Essays, page 243.

[51] Gough's edition of Camden's Britannia, folio, vol. iii. 170.

Boyle calls it "a mineral *sui generis*, approaching to a talc," and says that "it has nothing metallic in its nature [52]."

The finest plumbago that has ever been discovered is procured from a mine at Borrowdale, about six miles from Keswick, and in the neighbourhood of the lofty mountain of Skiddaw, in the county of Cumberland. I know of no other mine which produces this mineral in a state fit for making good black lead pencils [53]: it is on account of its

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[52] Boyle's Works, vol. v. page 27.

[53] Plumbago has within these few years been found of tolerably good quality, and in very considerable quantities, in an estate near Ayr

excellency therefore exported to all parts of the world [54]. The superior quality of this article is indeed so generally allowed, that on the continent the pencils made with it are called *crayons d'Angleterre.*

Dr. Campbell, in his Political Survey of Great Britain, says that this mine is private property, that it is opened but once in seven years, and no greater quantity than is equal to the

in North Britain. In some parts of that neighbourhood it occurs at the surface of the ground. It has been discovered also at a considerable depth at the foot of the mountains in the island of Ceylon. Cordiner's Description of Ceylon, 4to, 1807, vol. i. page 13.

[54] According to Dr. Campbell, this mineral is used with great success by dyers in fixing blue colours, vol. ii. page 38.

consumption is allowed to be sold. At the mine it is called *wadd*[55], and those who are concerned in raising it, suppose it to be impregnated with lead and antimony. Dr. Campbell himself considered it to be a mixture of talc and zinc[56].

Although the mine at Borrowdale may alone produce plumbago fit for making the best sort of pencils, there is a variety of other places where this mineral is to be found, and suf-

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[55] When this mineral was first raised, it was employed for marking sheep. It was afterwards used in medicine, for disorders of the bowels, and in nephritic complaints. Phil. Trans. No. 240, page 183.

[56] Political Survey of Great Britain, London, 1774, 4to, vol. ii. page 37.

ficiently good for all other applications. At present its uses are chiefly confined to the following purposes.

It is employed to make crayons and black lead pencils; to cover the best sort of iron castings to give them a shining coat, and preserve them from rust; to give a polish to small leaden shot; to rub on the cogs of wheels and other machinery, in order to diminish friction, and impart smoothness and lubricity to the parts which have most wear[57]; to mix mith pot-

[57] It is lamentable to perceive with what facility and success some people impose upon the public. Even the article of plumbago, or black lead, has been employed for purposes of quackery. The following is the substance of the specification of a late patent, dated

ter's clay for the production of some particular sorts of earthen ware; to make crucibles and other utensils which are to undergo intense heats; and, when kneaded with clay, to line all sorts of portable furnaces which are designed to be used in the

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the 6th of June 1812, for what the patentee calls his "Anti-Attrition Paste," 1 cwt. of plumbago to be mixed with 4 cwt. of pork-lard, or with a like quantity of suet, or of some one of the other articles enumerated in the specification, as may be seen in a periodical work called The Retrospect, No. 34, or in The Repertory of Arts, &c. No. 130. Surely this patentee could not be ignorant of the fact that such a mixture had long been used for similar purposes prior to the date of his patent, particularly in many of the manufacturing counties. In order, however, to

reduction of ores, and other chemical operations.

The natural incombustibility of plumbago peculiarly fits it for other purposes to which it has not yet been applied in this country; but especially for the covering of certain

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expose this pretension to originality the more effectually, the following recipe is selected from a printed volume, which may be had of any of the principal booksellers in London or elsewhere. "Mix one pound of hog's "lard with half a pound of black lead; stir "them well together, whilst melting over a "slow fire. If the axles and bushes of the "wheels be true, a carriage may safely be "run one hundred or one hundred and fifty "miles, with once using the above composi-"tion." The Family Receipt Book, Murray, London, 1811, page 414.

parts of wooden buildings to preserve them from accidents from fire.

Some time ago, a gentleman, a native of the state of North Carolina, informed me that a mine of black lead had been discovered in the neighbourhood of Raleigh, one of the cities of that state, which promises to be of very considerable consequence to the whole of North America. The mineral occurs in large solid lumps, and the mine is so extensive that it is thought to be inexhaustible. It is usually sold in its native state, packed in barrels, at 18*s.* or 20*s.* per cwt.

This native carburet of iron is used very extensively in the state of North Carolina for a variety of pur-

poses. They grind it with oil for painting the wooden roofs of their houses and even their best buildings. It is found to answer extremely well for preserving the wood from decay, and for keeping out the rain; and it is a great preservative against fire.

In America, where most of the fires are made with wood, accidents often happen from the circumstance of the sparks setting fire to the wooden roofs of their houses, and occasioning dreadful conflagrations: but this can never occur to those roofs which have been treated in this way; for I learn that the wooden shingles, which have been painted with two or three coats of this preparation, have been purposely ex-

posed to the full heat of a large fire for a considerable time, without their sustaining any injury [58].

The second kind of coal, which is called anthracolite, is seldom found but in the primitive mountains. It is generally amorphous, but sometimes occurs in a crystallized form. It is what was called glance-coal by Werner [59]; and as it contains more carbon than most of the common

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[58] This seems rather extraordinary, as one would have imagined that the oil would have still retained its combustible properties. It may, however, be a circumstance well worth the investigation of those who have it in their power to procure plumbago at a cheap rate.

[59] It is known also by the name of incombustible coal.

pit-coal, it may with propriety be classed next to plumbago. It burns slowly and without flame; its specific gravity varies from 1,300 to 1,500. This species is not considered to be of vegetable origin.

The third kind of coal mentioned above is jet and cannel coal. Both these varieties Werner denominates by the name of *black coal.* They are found in many parts of the world, and are often used in forming ornamental trinkets, particularly in France where they occur in abundance. The cannel coal acquired its name from the property it has of burning like a candle [60].

[60] In the Lancashire and Scotch dialect, candle is pronounced *cannel.*

In Scotland this bears the name of parrot-coal. It does not cake in the fire; and though it flames like a candle in the beginning of its combustion, this lasts but for a short time, and the residuum is considerable. The specific gravity of this coal is from 1,234 to 1,250. A specimen of the Lancashire cannel coal analysed by Mr. Kirwan contained 75 per cent. charcoal, 22 maltha, and 3 alumine and silex.

The fourth species includes all the varieties of the common pit-coal. These are composed of bitumen, carbon, and heterogeneous matters in different proportions, according to the places from whence they are procured. Some of these are black and

ponderous[61], and, from the quantity of bitumen and sulphur which they contain, burn very freely, and give out a great heat, though the combustion is of short duration. This sort generally contains a large admixture of martial pyrites, which

[61] A London architect having it in contemplation to construct an immense vault near the metropolis, for the purpose of storing coals, requested me to ascertain the specific gravity of this mineral, so as to afford him at least some practical information, and enable him to fix the dimensions of his vault to any given contents. This question evidently admits only of an approximation to the truth, and must depend upon the size of the pieces into which the coal is broken. Under this impression, I undertook a few experiments in the usual way, by filling a vessel of a known capacity first with water, which was weighed, and then with

sometimes occasions spontaneous combustion when they are laid in large heaps, and are exposed to the affusion of water [63].

There are other coals that burn very freely, which cake into a mass

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coals, taken from the heap large and small indiscriminately. In this way I found that the same cavity held more of the water than of the coals, in the proportion of 62.5 to 52.5; and the inference I have drawn from this calculation is, that we may consider ten feet cubic measure to be capable of containing 525 pounds avoirdupois of good Wallsend coals; or, in round numbers, whatever may be the size of a vault, that every sixty cubical feet of its contents will hold one chaldron, or 36 bushels of such coals as usually come to the London market.

[63] See vol. i. of these Essays, page 224 &c. and for a more detailed account of the several

when laid on the fire; these burn without any sulphureous smell [64], and

varieties of martial pyrites, consult Henckel's Pyritologia, 8vo, London, 1757.

"Hence sable coal his massy couch extends,
And stars of gold the sparkling pyrite blends:
Hence dull-eyed naphtha pours his pitchy streams,
And jet uncolour'd drinks the solar beams,
Bright amber* shines on his electric throne,
And adds ethereal lustres to his own."

* In most of the systems of mineralogy amber is considered as one of the varieties of pit-coal.

[64] There is a peculiar kind of hard coal raised at Pontetaive, a few miles from Swansey, which is much approved by those who are afflicted with some kinds of pulmonary disorders; for it burns like coke, and yields no smoke. It does not soil the fingers, and the chimneys never want sweeping. In consequence of this, many persons troubled with asthma have taken up their residence in that neighbourhood.

leave no residuum but a very inconsiderable quantity of ashes.

In some districts, coals are raised which have more the appearance of slate or schist than coal, and which only burn in consequence of the bitumen with which they are impregnated. These leave a bulky and stony kind of residuum, and are very unprofitable for most purposes.

There are other pit-coals which are so intimately mixed with sulphuret of iron that they become decomposed by the action of the air, and fall into dust, or what is called very small slack. Such coals are fit only for heaping upon large fires, for the burning of lime-stone, or the preparation of coke.

The decomposition of such coal by the accession of water is no doubt the origin of the hydrogen gas, or what is called the coal-damp of many of our collieries[65], and which often occasions deplorable accidents.

In Lancashire, the workmen get rid of this gas by sending down one of their party to set fire to it, which he does with safety to himself by

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[65] In the second volume of the Philosophical Transactions for the year 1667, mention is made of a well, situated near the mouth of a coal-pit, in the road that leads from Warrington to Chester, which at that time took fire whenever a lighted candle was brought near to it. Other cases of a similar kind are mentioned in a note to the second of these Essays, vol. i, page 228. See also note 63.

lying flat upon the ground, and letting it explode over him.

A method of clearing a coal-pit of the coal-damp, by making a fire and fixing pipes to occasion a circulation, as described by Sir Robert Moray, more than a century ago, may be seen in the Philosophical Transactions, vol. i. page 79, accompanied with a drawing of the whole of the apparatus.

As coal-pits have been worked in different parts of Europe for almost time immemorial [66], it seems surprising that the proprietors have not long

[66] According to Wallis, in his History of Northumberland, the coal-pits in the north of England were worked when the Romans were in possession of this island.

ago investigated the nature of this fire-damp, as it is usually called, and devised methods of clearing the mines of it, so as to prevent the numerous accidents which we often hear of as happening in these subterranean caverns.

We read that so lately as the year 1763 the nature of this inflammable air of coal-pits was so little known in Dauphiné, that the intendant of the province took measures to discover whether the fire that happened in consequence of it, was not the work of some ill-intentioned persons. The Sieur Finant, surgeon at Briançon, and many others, were so fully possessed with this idea, that, in the prosecution of it, they exposed them-

selves so as to be grievously scorched and bruised by the action of the inflamed vapour; particularly the Sieur Finant, who was thought likely to be a perpetual cripple, in consequence of his ignorance of this branch of subterranean philosophy [67].

The situations in which coal is found are as various as the composition and properties of the several species of coals themselves. In the counties of Glocester, Worcester, and Stafford; at Newcastle upon Tyne, in the neighbourhood of Sunderland, and in many other parts of the kingdom, the coal is raised from very con-

[67] Monthly Review, vol. xxxvi. page 553, from the History of the Academy of Sciences at Paris, for the year 1763.

siderable depths; but in the vicinity of Stainthorpe, in the county of Durham, nothing more is necessary than to pare off the turf, and dig out this valuable production at the surface of the ground.

This coal is of excellent quality, much superior to that which is raised in Northumberland, and brought to the London market. If a railway were made from Stainthorpe to Stockton on Tees, this coal might be conveyed thither at a small expense, and from thence coastwise to London, to the great advantage of the metropolis, and to the enrichment of the district from whence it is to be procured.

A very singular kind of coal is found near the village of Seaton, in the neighbourhood of Hartlepool, in the county of Durham, which is brought up by the tide, and that only occasionally. It is in the form of very coarse sand, the grains of which are so polished, that they may be handled freely without soiling the hands, and yet they are so small, that it would be difficult, among a large heap, to find a piece larger than a cherry-stone.

This coal, which abounds with bitumen, and consequently makes excellent fuel, is generally left by the tide on the sea-shore, in a continued ridge, extending sometimes from a

quarter of a mile to a mile in length, three or four inches thick, and only of a few feet in width.

As a considerable time often elapses between the periods when these supplies arrive, a very interesting scene is exhibited whenever one of these strata is thrown up by the tide. In an instant, as it were, all the inhabitants of the village hasten down to the shore, and are seen busily employed in raking it together, and in carting it away before the return of high water, which would wash all that remained off the shore.

Thus, by the bounty of Nature, are the poor of the whole neighbourhood supplied with an article of the first necessity; and merely by a little

industry in the summer months, are they enabled to lay up an ample store of excellent fuel for the whole of their winter's consumption.

In closing this Essay, it may not be irrelevant to remark, that if a line be drawn upon the map of England, across the country from Sunderland to Bristol, all the counties on the west of this line will be found to contain coal[68]. Formerly these were the least valuable districts, and the parts of the country which were the

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[68] Coals are also found plentifully in Scotland; but, a line drawn on the south of the Tay from the bank opposite to Dundee, along the Ochil hills to Stirling, is esteemed the northern boundary of the coal of this island.

most thinly populated. Hence, when the constitution of the British Parliament was established, the greatest weight of representation was given to the rich counties which were on the other side of that line. Whereas, now, owing to the establishment of manufactures, the coal-counties have become the most populous and wealthy, and the agricultural districts have either been comparatively deserted, or at least have not much increased in population.

This accounts in some measure for the inequality of our representation, and shows, very distinctly, the value of our mines of coal, and that by the establishment of manufactures, even the most sterile and forbidding

country may be rendered populous, flourishing and opulent[69].

We are, however, much indebted to the wisdom of our government for our success as a manufacturing nation. It is the true policy of every state desirous of becoming eminent in manufactures, to export none of the native materials which its own people can fabricate, nor to import any thing which the wants of

[69] The consequences of the establishment of manufactures have been peculiarly striking in some parts of Austrian Flanders. The industry of the inhabitants of Brussels has been such, that an acre of land in the environs of that city, will yield in manufactures an amount equal to the revenues of the whole province of *Champaigne*. Carrard on the Spirit of Legislation, page 313.

the state may demand, but in the condition of raw materials; and this for many centuries seems to have been the basis of all our commercial regulations.

In the early periods of our history the woollen manufacture was confined chiefly to the people of Flanders and the Netherlands; but when, in the year 1331, Kempe, a famous Flemish manufacturer, came into this country, that wise prince, Edward III. took him under his immediate protection, and published a proclamation, promising the like patronage and favour[70] to all foreign weavers

[70] Many years after this, the same patriotic prince invited John Uninam, William Uninam, and John Lutuyt, of Delft, and granted them

and fullers, who would come and settle in England[71].

The parliament seconded the patriotic views of that prince, and in the year 1337, made it felony to export wool, whether it was done by foreigners or denizens[72]. Afterwards Henry VI.[73] invited John de Shei-

his royal protection to exercise their trade of clock-making in any part of his kingdom, without molestation. Rym. Fœd. tom. vi. page 590.

[71] Rymer's Fœd. tom. iv. p. 496.

[72] Ruffhead's Statutes at Large, vol. i. p. 221. Henry's Great Britain, 8vo, vol. viii. p. 282.

[73] This same prince, in the year 1452, invited Michael Gosseleyn, George Hartryke, and Matthew Laweston, three miners, with thirty assistants from Germany, to superintend and work the royal mines, and instruct his subjects in their art. Rym. Fœd. tom. ii. p. 317.

dame, a gentleman of Zealand, with sixty persons in his company, to settle in England to instruct his subjects in the new method of making salt, promising them protection and encouragement[74].

In the reign of Queen Elizabeth another act of parliament was passed to prevent the exportation of English wool; and to encourage the woollen manufacture still more, in the year 1666 it was enacted that no corpse should be buried in any thing but woollen[75]; and from that period to

[74] Rym. Fœd. tom. viii. p. 761.

[75] The more effectually to secure this source of national wealth, the woolsacks on which our Judges sit in the House of Lords were placed there, I suspect, to remind them that

the present times, we all know how alive each succeeding government has been to the interests of every class of British artists[76], and to this end how successfully they have prevented the introduction of any of the manufactures of France[77].

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in their judicial capacity they ought to have a constant eye to the preservation of this staple commodity of the kingdom.

[76] England is, I believe, the only country that has ever appropriated any part of its revenues to furnish bounties for the exportation of manufactured goods.

[77] So early as the 1st of Richard III. an act was passed to prohibit the importation of the different kinds of cutlery and various utensils in iron and copper, all of which are enumerated in the act. See Statutes at Large, 1 Rich. III. chap. 12. In the short reign of Henry IV. no less than twelve acts of parlia-

But to the patient and unremitting industry of our mechanics, and the frugality of their habits, wé are perhaps still more beholden for our success as a manufacturing people[78].

ment were passed to protect the woollen manufacturers, and to prevent the importation of manufactured woollen goods. King Charles I. in the sixth year of his reign issued his royal proclamation, forbidding the clothiers to import iron wire, or cards made with foreign wire; and on the 19th of August, in the fourteenth year of the same reign, another proclamation was issued against the importation of latten (brass) wire for the same purpose. Pettus's Fodinæ Regales, folio. London, 1670, pages 70 and 71.

[78] I have read of an Emperor of China, who, when he was about to suppress the monasteries of bonzes, declared aloud to the mandarines of the nation, that if he had a man that did not labour, or a woman that did not

Unlike many of the nations of Europe, who through indolence or inattention suffer the richest treasures of Nature to remain undisturbed in the bowels of their respective countries[79], it has become a custom among us to husband all our resources, and to appropriate every thing, even down

spin, some one must suffer cold or hunger in the empire.

[79] There is a remarkable instance of this negligence in that extensive district called the Pays de Vaud, on the Lake of Geneva. Though the inhabitants of their towns require every luxury that can be procured, neither iron, steel, earthen-ware, nor glass, is made among them, although they have all the necessary materials in great plenty; and even though their wines are abundant, they depend upon foreigners to supply the vinegar for their home consumption.

to the very residuums of our manufactories, to some useful purpose.

To what degree of excellence our manufacturers may arrive in the economy of their materials, when chemical science is better understood, and a knowledge of her laws more generally diffused among our native mechanics, it is impossible to conceive; but this is the point in which we are most deficient, and these, I am persuaded, are our most important desiderata, and which every person who has any influence in the country should do his utmost to supply.

Notwithstanding our general pre-eminence in manufactures, it has generally been allowed that the French

surpass us very much in the arts of dyeing; and Mons. Carrard has told us that it is to chemistry that the French are indebted for the progress which this art has made among them; the king's ministers having successively invited the most able chemists to review it; and that by their assistance it is, that it has been carried to the highest degree of perfection [80]. Besides which, the Academy of Sciences in France is rendering such daily services to her manufacturers, as ought to excite our emulation, and rouse our anxiety, not to be outdone in what may be called our own pe-

[80] Carrard's Prize Essay on the Spirit of Legislation. London, 1772, page 332.

culiar element. I must not, however, enlarge, and therefore shall conclude with an observation of Dr. Home's [81] on this subject.

"I consider it," says he, "as a loss to the arts and manufactures of Great Britain, that we have not an academy established by the public authority and expense, for attending to their progress. The members of this academy, having an honest necessity of pursuing their genius, might without any inconvenience give ear to the voice of fame. It has cost very little to France for her Academy of Sciences; and yet what advantages has

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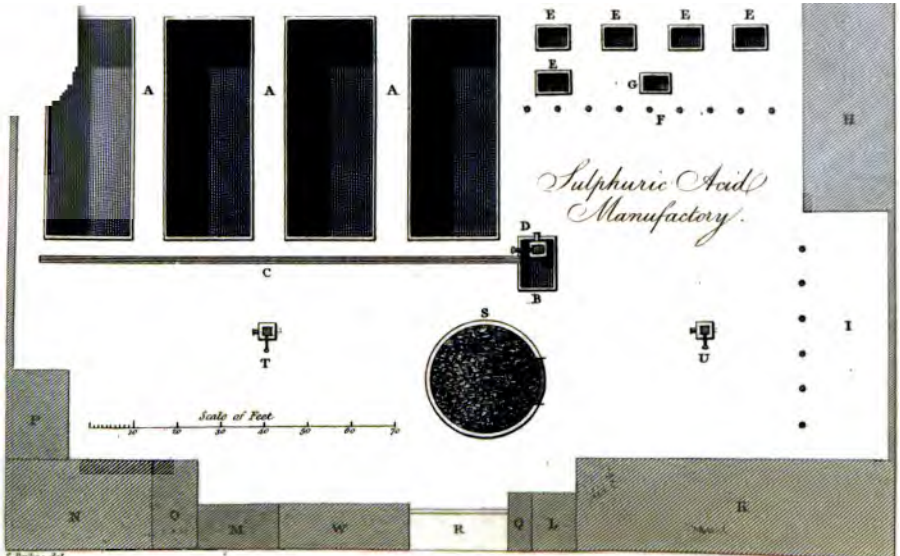
[81] Home's Experiments on Bleaching. Edinburgh, 8vo, 1756.

it procured to the arts and manufactures of that country! It is to this that the French owe their superiority in many of the arts. In establishing this academy, Louis XIV. triumphed over those whom he could not vanquish by his arms."

ESSAY VII.

ON

SULPHURIC ACID.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Manufactory.
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ESSAY VII.

ON

SULPHURIC ACID.

When sulphur mixed with a certain portion of nitre is burnt over water, in a closed vessel containing atmospheric air, a peculiar acid is formed during the combustion, which is known to chemists by the name of SULPHURIC ACID.

This acid is formed in many of the operations of nature[1]; but we

[1] Disengaged sulphuric acid has occasionally been found native, in some parts of Italy. Journal de Phys. tom. vii. page 395.

have no reason to believe that the ancients knew this, although they were well acquainted with its base, sulphur[2], which they sometimes employed with other combustible substances in religious oblations.

Vitriol, or sulphate of iron, is mentioned by Pliny in his Natural History; but it does not appear that he knew any thing of its chemical composition.

The first mention of sulphuric acid occurs in the writings of Basil Valentine, a celebrated chemist of Erfurt. In his time, however, the quan-

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[2] So early as in the first century sulphur was employed in bleaching woollen cloth, and for other purposes. Pliny, lib. xxxv. cap. 15.

tity produced must have been small, and its consumption very circumscribed. It was also known to Paracelsus, the noted Swiss alchemist, who died so early as the year 1541; and it is evidently referred to likewise in a work entitled *De Re Metallica*, which was published by George Agricola, a German physician, in the year 1542; but I know of no proper characteristic description of this acid by any of the writers of that period. The first person who gave any thing like a correct account of sulphuric acid was Gerard Dornæus, in a work which he published in the year 1570; and again in another edition of the same work, which

he republished at Frankfort in the year 1581[3].

When sulphuric acid was first prepared by art, it was distilled from dried sulphate of iron[4], or the common *green-vitriol* or copperas, as it is vulgarly called, of commerce[5].

[3] This work is entitled "Congeries Paracelsicæ Chemiæ de Transmutationibus Metallorum, ex omnibus quæ de his ab ipso scripta reperire licuit hactenus; access. Genealogia Mineralium atque Metallorum omnium." 8vo, Francf. Wechel. 1581.

[4] Sulphate of iron is prepared from martial pyrites, which is a native sulphuret of iron. It is found in abundance on the island of Sheppy and elsewhere. By exposing this to the air in large beds, oxygen is absorbed, the sulphur becomes sulphuric acid, and the new-formed salt is separated by washing, &c.

[5] All the sulphuric acid which is prepared

Hence, when the component parts neither of the salt nor of the acid were known, it was very naturally called *oil*[6] of vitriol.

This name should now be expunged, as it tends to give false ideas

in Saxony, and in many other parts of Germany, is still procured from sulphate of iron. In the Journal de Physique there is a very particular account, by Mr. Fragoso, of the distillation of this acid from copperas, as it is now practised at Bleyl, a village in Bohemia. An abridgement of this account may be seen in the thirteenth volume of the Repertory of Arts, page 269.

[6] Sulphuric acid probably acquired the name of *oil* of vitriol from the circumstances of its resemblance to oil in adhering to the sides of a vessel containing it, and in its occasioning little noise when poured from one vessel to another.

of the nature of the acid, and may mislead and bewilder a young chemist. Oil does not mix with water, and it is composed of hydrogen and carbon; but neither of these substances enters into the composition of sulphuric acid, which has been demonstrated by analysis, as well as synthesis, to be formed only of sulphur, oxygen, and water.

The makers of sulphuric acid having found great inconvenience in procuring it from sulphate of iron, on account of the length of time which was necessary for the operation[7], the small quantity of acid

[7] To conduct the operation in the best manner, seven or eight days will be required, and

that was procured by this means[8], and the intense heat required for its distillation, which always destroyed the stills with great rapidity, and entailed upon them a perpetual and enormous expense[9], had recourse to

during two thirds of this time the fire must be kept at the highest pitch.

[8] Bernhardt, who was well acquainted with this process, tells us that he procured only 64 pounds of sulphuric acid from six hundred weight of sulphate of iron. Directions for conducting the operation may be seen in Glauber's Works, folio, London, 1689, page 17. According to him, a much purer sulphuric acid may be obtained from sulphate of zinc, and with less labour.

[9] At one time the English makers of sulphuric acid distilled the vitriol in earthen vessels called long-necks, placed within a reverberatory furnace, with a glass receiver luted

the base itself, to the sulphur, which, in conjunction with nitre, was burnt in very large globes of glass, and the product was concentrated by boiling it in retorts or other glass vessels, till the fluid was of a sufficient strength for sale.

It may be proper, however, before we proceed with the account of the manufacture of sulphuric acid, to say a word or two respecting the sulphur.

Sulphur, or brimstone, as it has usually been called, is a simple combustible[10] substance, quite undecom-

to each retort. It was usual to put fifty or more of these into one furnace. Dr. Lewis's edition of Neumann, vol. i. page 277.

[10] Stahl found that an ounce of sulphur,

posable, at least by any of our present methods of analysis, and it differs in its nature and properties from all other known bodies. It is chiefly procured in the neighbourhood of volcanoes, and also from some of the native sulphurets. Its chief consumption is in the manufacture of sulphuric acid; though it should be recollected, that if sulphur be burnt slowly[11], and without any admixture,

burnt with a wick, may be made to yield a constant flame for six hours; and that, when the wick was very small, only 15 or 16 grains were consumed in an hour. Lewis's Neumann, vol. i. page 255.

[11] When sulphur is heated to about 190° combustion begins, and a pale blueish flame is emitted with the production of a very small degree of heat. The heat thus gene-

sulphurous and not sulphuric acid will be formed.

I have seen no account of the preparation of sulphur in any of the modern systems of chemistry. A few particulars relating to the process appear in an early volume of the Philosophical Transactions, which I shall insert, believing they will be acceptable to the reader.

" The mineral out of which brimstone is extracted at Liege, is not much unlike lead-ore, having also oft-times much lead mingled with it,

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rated is so inconsiderable that Baumé contrived to burn off the whole of the sulphur from a quantity of gunpowder without exploding the powder. Macquer's Dictionary, article *Sulphur*.

which is separated from it by picking. To make brimstone, they break the ore into small pieces, which they put into crucibles made of earth, five feet long, square and pyramid-wise. The entry is near a foot square. These crucibles are laid sloping, eight undermost, and seven above them, as it were betwixt them, that the fire may come at them all, each having its particular furnace or oven. The brimstone being dissolved by the violence of the heat, drops out at the small end of the crucible, and falls into a leaden trough or receiver common to all the said crucibles, through which there runs a continual rivulet of cold water, conveyed thither by pipes for the cool-

ing of the dissolved sulphur, which is ordinarily four hours in melting[12]." From the ashes left in the crucibles they afterward make crystallized sulphate of iron[13].

The process of forming sulphuric acid by the combustion of sulphur is so very different from the original method of procuring it by the simple distillation of sulphate of iron, and has occasioned such important changes in a variety of the manufactures of the country, that I have considered it my duty to take some

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[12] Philosophical Transactions for the year 1665, page 45.

[13] The method of extracting sulphur at Goslar may be seen in Dr. Lewis's edition of Neumann, vol. i. page 264.

pains to trace the progress of the new method; especially, as it will in a few years be difficult to acquire any correct information on the subject, and as, from my connection with the family of one of the principal original manufacturers, I am in possession of some facts which I am desirous of communicating to the public. Moreover, the gratification which arises from being the means of recording the origin of a manufactory of so much importance, and a discovery so much to the honour of the British empire[14] as the process for

[14] When the state of chemical science at the date of this invention is considered, one can scarcely hesitate to pronounce this to be one of the greatest efforts of human genius, as

producing this acid in an economical way, will, I trust, be my excuse for allowing the following detail to occupy that room which some may think ought to have been devoted to a different purpose.

The process of forming sulphuric acid by combustion was first adopted [15] in this country by Dr. Ward,

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neither the nature of nitre, nor of the process of combustion, was at all understood.

[15] It has generally been said that Dr. Ward was the author of this important discovery; but Fourcroy attributes it to two French chemists, Lefevre and Lemery. The works of the latter I have consulted, and in an edition printed more than a century ago, I find an express process for producing sulphuric acid by the combustion of sulphur and nitre; though it is probable that before Dr. Ward's

the vendor of a noted analeptic pill, and the inventor of the *white drop*, and some other celebrated nostrums, which bear his name. An exclusive right to this mode of making the acid was granted to the doctor by patent; and, by way of distinction, the article which he prepared was called "Oil of vitriol made by the bell," and it was sold from 18*d.* to 2*s.* 6*d.* per pound.

The glass vessels which were employed for this process were made with wide necks, and as large as they

time the quantity made in this way was very inconsiderable; for Lemery tells us that he prefers the acid made without nitre. Fourcroy's System of Chem. Knowledge, London, 1804, vol. ii. page 83. Lemery's Chemistry, London, 1698, page 448.

could be blown with safety, and capable of holding forty or fifty gallons. These were placed in two rows on a bed of sand, and at a sufficient distance from each other to be conveniently approached. A few pounds of water being poured into each glass, a stone-ware pot was introduced into the neck, and on this was placed an iron ladle previously made red-hot. Into this last, by means of another ladle of tin-ware, a mixture of sulphur and nitre was put, and then the aperture of the glass vessel was immediately closed with a stopper of wood. The heat of the iron ladle set the sulphur and nitre on fire; and when the combustion was finished, the iron ladle was taken

out, and the vapours suffered to condense.

The same operation was successively conducted in each of the glass vessels composing the two rows; so that the workman, after passing through the whole range, arrived at the first vessel at the time when the vapours were totally condensed, and the vessel consequently in a state to receive a new portion of the matter [16] for burning.

The British manufacture of this acid was thus monopolised by Dr. Ward for a considerable time: at

[16] About the same time, or soon after Dr. Ward commenced this process in England, a similar plan was adopted in Holland to a large extent. See Thomson's Fourcroy, vol. ii. page 158.

length chambers of lead were employed for the combustion of the sulphur and nitre, which were so contrived that the floor of each might be constantly covered with a sheet of water, capable of absorbing the sulphuric acid gas at the time of its formation.

The introduction of the leaden apparatus is a memorable event in the history of the progress of this manufacture, as it has laid the foundation of its present magnitude, and in a very short time reduced the price to about one quarter of its former rate.

The credit of this very important improvement belongs to the late Dr. Roebuck, an eminent physician of Birmingham, who, in conjunction

with his partner, the late Mr. Samuel Garbett [17], erected the first leaden chamber for this purpose, at Birmingham, about the year 1746; and the same works are now in the occupation of their successors, Messieurs Alston and Armitage.

Owing to the interior situation of these works, and the great expense and risque of land carriage, there being at that time no conveyance by canals, the consumption was almost entirely confined to that town and neighbourhood. A considerable portion of the acid was employed in the distillation of nitrous acid, which is

[17] These gentlemen were violently opposed by Dr. Ward, who considered their establishments as invasions of his patent.

in great demand there for the use of the various manufactories. Much of it was also used as a solvent for copper, for the double purpose of making Roman-vitriol, and of recovering the gold and silver from waste gilt and plated metal.

These manufacturers, however, were not long satisfied with this confined consumption: in order therefore to create a more extensive demand, and likewise with a view to the introduction of it for the purpose of bleaching in the linen manufactories of Scotland and Ireland, in the year 1749 they established works at Prestonpans on the eastern coast of Scotland on a very extensive scale.

That nothing might be neglected

which was likely to promote this object, Dr. Home, then professor of chemistry in the university of Edinburgh, entered upon a course of experiments to ascertain the powerful effects of sulphuric acid, when properly employed, in whitening linen cloth without prejudice to the fabric. These experiments were afterwards published, together with directions as to the mode in which the new agent ought to be employed. This, by degrees, had the desired effect, and finally exploded the use of sour milk, which, till then, was the only acidulous article that had ever been used in bleaching.

Dr. Roebuck, whose memory is held in great esteem at Birmingham,

was a man of very superior talent, of the most amiable manners, and very considerable acquirements[18]; but he cannot properly be said to have been the *sole* founder of the works at Prestonpans, or of the great iron works at Carron, as is asserted by a writer in one of the Encyclopedias.

In the former of these he was connected from the very first outset of the business with Mr. Garbett, who,

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[18] The peculiar intimacy which long subsisted between Dr. Roebuck and the illustrious Dr. Black, is of itself alone sufficient to show that the former must have been a man of superior endowments. Dr. Robison, in his preface to Black's Lectures, quarto, page 69, speaks of this intimacy in very respectful terms.

as a merchant, was also a man of highly distinguished abilities. Of the latter, the Doctor and his three brothers, together with Mr. Garbett, and Messieurs Cadell and Sons, of Cockenzie near Prestonpans, were the original projectors and founders, (I mean of the vast work at Carron,) to the great prejudice of their respective fortunes, from the immense outlay of money required to carry their plan into execution. This, with an unfortunate concern in a colliery at Borrowstoness, brought ruin on all the Doctor's fair prospects in life [19].

In reverting to the manufacture of sulphuric acid, it ought to be no-

[19] This excellent man died on the 17th of July 1794.

ticed that for several years Messieurs Roebuck and Garbett carried on their works in England and Scotland with great success and without any opposition. They not only supplied the demands of Great Britain and Ireland, but exported very large quantities of sulphuric acid to the continent of Europe.

These establishments had continued to increase, and were become of very considerable importance, when an untoward accident gave rise to an opposition which spread the first cloud over their future prospects.

It was about the year 1756, when one of their workmen at Birmingham, who was a hired servant, absconded from their service, and his misde-

meanours and refractory conduct rendered it inexpedient to attempt to reclaim him. This man being a native of Bridgenorth, he went thither, and had the art to induce a Mr. Rhodes[20], an eminent seed-crusher of that town, to embark in the business.

A small work was accordingly set up at Bridgenorth, on the banks of

[20] A daughter of Mr. Rhodes, a woman of fine taste and considerable acquirements, still lives at Bridgenorth, and is now soliciting subscriptions to a volume of poems which she intends publishing. This lady is the author of several papers in the Transactions of the Society for the promotion of Arts, Manufactures, and Commerce, on the manufacture of silk in Great Britain, and for which the silver medal of the society was awarded her.

the Severn, and there the manufacture was carried on for many years. This man did not, however, continue long with Mr. Rhodes; but engaged himself to Mr. Skey of Bewdley, who had just begun a manufactory of sulphuric acid, on a scale much larger than that at Bridgenorth which I have just mentioned.

This establishment was also on the banks of the Severn, at a place called Dowles, near the town of Bewdley, in the county of Worcester, and was the third English work for manufacturing this valuable commodity by the combustion of sulphur in leaden chambers.

At first, these chambers were only

six feet square; but Mr. Skey erected his of ten feet square, and in vessels of that size he continued the manufacture for many years.

These chambers were erected under the direction of a man who had formerly worked at Prestonpans, and who, having been discharged from thence, was travelling through the country with his family in search of employment.

The above-mentioned Mr. Skey, who was a man of great enterprise, having by accident seen this individual and heard his account of the nature of the business, at once determined that he would engage in it, and manufacture the article on as

large a scale as its demand should require.

Such was the origin of the manufactory at Bewdley; and as the materials at that time were cheap, and the acid was sold dear, this establishment was the means of raising its founder to a state of great opulence, and it is carried on even at the present day for the benefit of his descendants.

Considering the nature and importance of Dr. Roebuck's improvement, it is a remarkable circumstance that similar establishments were not sooner formed in various parts of the kingdom; and that twenty-five years should have elapsed before any

spirited individual in the metropolis, or in its vicinity, had availed himself of the advantages of the invention.

According to the best information which I have been enabled to obtain, Messieurs Kingscote and Walker, druggists of London, were the first persons, south of Birmingham, who attempted to make sulphuric acid in vessels of lead. Their manufactory was established in the year 1772, at Battersea, four miles from London, and on the 24th day of December 1771 the first barge-load of lead was navigated on the Thames up to Battersea for the construction of the chambers.

This establishment consisted of

seventy-one circular leaden vessels, each six feet in diameter and six feet in height, and were constructed in the following manner: A sheet of lead was folded round a wooden cylinder prepared for the purpose, and upon this immense maundrel the vessels were formed into shape, and then the edges of the sheets were lapped together and soldered. Each vessel was afterwards reared on one end upon a bottom of lead, and when thus fixed, it was covered with a dome of lead firmly soldered upon it.

These receptacles had each one aperture, which, during the time of the combustion of the sulphur, was closed by a door of mahogany nicely adapted to it: besides which,

each vessel had an outer door of the same species of wood to be shut before the former, in order to close the opening the more effectually. These rooms stood in five separate rows, independently of each other, and all were inclosed in one large brick-building, to preserve them from the effects of the sun and wind.

Besides the apparatus which I have described, these manufacturers erected also several square houses of lead, which were perfect cubes of twelve feet each; and these, together with the former, were regularly employed for many years. I have been the more particular in describing this work, as I conceive it to have been the most curious and expensive esta-

When the formation of sulphuric acid by combustion in leaden chambers was completely established by Dr. Roebuck, little or no improvement was made in the manufacture for many years. However, in the year 1788, a memorable era in the history of the trade of this country, when the new method of bleaching by oxymuriatic acid was introduced, the sale of sulphuric acid was much increased, especially in some particular districts. From this time the demand became enormous, and almost unlimited in extent; so that, from this single and unexpected circumstance, the manufacturers of this acid found it necessary to erect chambers of much larger extent for the combus-

tion of the sulphur; and these have been enlarged again and again by the great makers, so that now a common rate manufactory for sulphuric acid is really an establishment of serious concern, in respect to capital and magnitude.

The size of the leaden chambers in modern use is from 20 feet long and 12 feet wide, to 40 or 60 feet long and 16 or 18 feet wide[21]. One manufacturer, however, in Lanca-

[21] Chaptal, who was a scientific manufacturer of sulphuric acid, says "Those chambers which are about twenty feet broad by twenty-five long and fifteen high, seem to me to be of the most advantageous proportions." Chemistry applied to the Arts, vol. iii. page 40.

shire has a leaden chamber of the enormous dimensions of 120 by 40 feet, and 20 feet high, consequently forming a space of 96,000 cubic feet. It is impossible, indeed, to say to what extent the enlargement of these vessels may not be carried by the opulent manufacturers, who seem to set no bounds to their expenditure, especially as we are at present in possession of no facts by which it is possible to determine which is the best form, or what is the best size of a House[22] for the manufacture of sulphuric acid.

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[22] House is a technical name for these leaden chambers. In some districts they are called leaden vessels.

The process, however, whatever may be the size of the chambers, is generally conducted similarly, and in this way. A quantity of common brimstone, coarsely ground, is carefully mixed with crude saltpetre[23] in the proportion of seven or eight pounds of the former to one pound of the latter; and this mixture is afterwards divided into separate charges, containing quantities proportioned to the size of the chamber in which they are intended to be burnt.

[23] I never heard of *refined* nitre being used for this purpose; and yet many of the manufacturers of sulphuric acid instruct their brokers to purchase only such lots for them, at the sales of the East India Company, as have a small refraction, as it is termed, and are consequently esteemed to be of superior quality.

The best method for apportioning this mixture appears to me to be this: to allow one pound for every 300 cubical feet of atmospheric air contained within the chamber; that is, if a house be an oblong square of 40 feet by 15 feet, and 15 feet high, the contents in cubic feet will be 9,000, and such a chamber will take 30 pounds of the mixture at each charge.

The mixture of sulphur and nitre is usually spread upon several plates either of iron or of lead; and these are afterwards placed upon stands of lead within the chamber, at some distance from each other, and a foot or two above the surface of the water. Things being thus arranged, the sulphur is lighted by means of

a hot iron, and the doors are then closed.

If well mixed, the brimstone and nitre will soon be in rapid combustion, which will continue for 20 or 30 minutes, during which the chamber will become entirely filled with gas.

Three hours, calculating from the time of lighting, are generally allowed for the condensation of this gas; and then it is customary to throw open the doors for three quarters of an hour or an hour, for the free admission of atmospheric air and the expulsion of all the incondensable gas, in order that the house may be thoroughly sweetened, as it is called, for the next burning.

During this interval the plates are again charged, and preparation is made for a fresh combustion, which is thus repeated every four hours, day and night, without intermission, till the water at the bottom of the chamber is thought to be sufficiently acidified [24], when it is drawn off, by means of a syphon, into a reservoir of lead, conveniently placed for its reception, and the floor of the chamber replenished with water for another making.

[24] Some manufacturers make it a rule to remove the acid out of the chamber when it begins to turn black; and this, I think, generally happens when it is of a specific gravity between that of 1,350 and 1,450; though I suspect that most of the makers suffer it to remain until it acquire a specific gravity of at least 1,560.

Whatever number of leaden chambers a manufactory may consist of, it is customary to work them all in this way, day and night, without interruption: for, as it requires a large sum in the first instance to form a sulphuric acid establishment, the operation being tedious, the return slow, and the product very small compared with the capital, the interest of money must be a heavy charge on the trade; and this is a constant spur to the manufacturer, making him anxious to get as large a produce as possible from each chamber.

When the acid has been drawn from the house, it is pumped from the reservoir into a large leaden boiler, which is usually an oblong square,

and there it is heated till a copious vapour arises from its surface, when the operator ceases to increase the fire; still, however, keeping the liquor steaming day and night, till it has acquired that exact specific gravity, at which he considers it to be most economical to stay the process.

Where a proper attention is paid to the saving of labour, another reservoir is provided which is placed contiguous to the boiler, and into this the concentrated acid is syphoned, where it is preserved, closely covered from the action of the atmosphere, till it is convenient to remove it to the rectifying house. There it is boiled in retorts of glass, till the remainder of the sulphurous

and nitrous gas is driven off, and the acid has acquired the usual concentration for sale.

To explain why these different operations are necessary for procuring sulphuric acid in its highest state of concentration, it may be remarked, that whenever the acid in the leaden chambers has acquired a certain specific gravity, it will refuse to absorb the gas with the same avidity as at first; therefore, in order to conduct the process economically, the acid liquor must then be removed, and water poured in to supply its place.

It is equally necessary, when in the boiler, to draw it off before it becomes too much concentrated; for the boiling point of sulphuric acid always

increases with the increase of its specific gravity; and its boiling point is so very near to that at which lead melts[25], that there would be great danger of the metal giving way, were an attempt made to concentrate the acid beyond a certain point in such utensils; to say nothing of the loss of that portion of acid which would be decomposed by the metal, and of the impurity which the remaining acid would acquire from the large quan-

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[25] According to Irving, lead melts at 594 of Fahrenheit; and Dalton states that the concentrated sulphuric acid of commerce of the specific gravity of 1,848 boils at 590°; but if the specific gravity amount to 1,849, it will require a heat of 650° to bring it to the state of ebullition.

tity of lead that would be then dissolved.

Some manufacturers are, indeed, so curious in the quality of the article, that they never steam it in lead at all, but remove it at once from the chamber of combustion to the retorts of glass. This is, doubtless, the best way of conducting the manufacture; for acid thus prepared can contain but a very minute portion of lead, it having no opportunity of acting very sensibly upon that metal[26].

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[26] The sulphuric acid of commerce always contains a portion of lead, and sometimes a small quantity of the sulphate of potash. Whenever sulphuric acid is required to be pure for chemical experiments, or medicinal purposes, distilled water should be added to some of the

Having thus given but a brief account of the nature of this manufacture, it will be necessary to add a few words upon the properties of the acid which is the subject of this Essay.

I have already noticed that sulphuric acid is a compound of sulphur, oxygen, and water. The proportions which are probably the most accurate of any that have been given are those of Mr. Dalton, who states that the acid of commerce of the specific gravity of 1,847 is composed thus, omitting fractions, viz. of

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common acid of the shops, till these impurities are all precipitated; and, if necessary, the water might then be abstracted by evaporation in a glass vessel.

30 parts of sulphur—48 of oxygen—and 22 of water[27].

When this acid is pure it is entirely devoid of colour and smell; it is extremely acid and corrosive[28],

[27] It must be recollected, that though these are the real proportions of sulphuric acid, no method has yet been discovered of making any thing like the quantity of acid from a given weight of the sulphur which these proportions indicate.

[28] As the uses of sulphuric acid are become so various, cases may occur of its being taken into the stomach by mistake, and without immediate relief its corrosive properties would produce fatal effects. If magnesia should be at hand, that earth mixed with water and sweetened with sugar, would be the best possible antidote to the poison; but in case this could not be immediately procured, soap-water, which can be furnished by all families, and which is

and one of the most ponderous fluids we are acquainted with. It is capable of uniting with the earths, the alkalies, and most of the metallic oxides, and in these combinations it forms those salts which are known by the name of sulphates.

The most distinguishing characteristics of sulphuric acid are, its peculiar affinity for barytes, which it is capable of separating from all its

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one of the next best remedies, should be drunk plentifully. The late unfortunate death of an infant son of the Hon. and Rev. E. Knox, at Dungarvon Park, in consequence of his swallowing a quantity of oil of vitriol which had been carelessly left on the table by a female domestic, shows how important it is for the public to be acquainted with the proper remedy in such cases.

other combinations; and its attraction for water, which it absorbs with great avidity, even from the atmosphere[29], whenever it is exposed to it, in a state of concentration.

If a thermometer be placed in a glass of water, and concentrated sulphuric acid gradually added, the mercury will instantly begin to ascend, and progressively to a certain extent[30]. But if two pounds of

[29] The attraction which sulphuric acid has for water is so powerful, that in certain chemical operations it is often employed for the purpose of creating a dry atmosphere.

[30] The great affinity of sulphuric acid for water may be shown by the following very easy experiment: If the bulb of a thermometer be dipped in concentrated sulphuric acid, it will probably not be perceived that the immer-

this acid be suddenly mixed with one pound of water, the temperature will immediately be raised much higher than that of boiling water [31].

No advantage, however, has ever been taken of this property of sulphuric acid, though it affords the means of furnishing a variety of de-

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sion has occasioned any alteration in the temperature of the thermometer; but if it be withdrawn and held in the open air, the small portion of acid which adheres to the bulb will absorb water from the atmosphere with so much rapidity (especially if it be in damp weather) that in a few seconds the mercury in the thermometer will be seen to rise several degrees.

[31] On the contrary, it may be remarked, that if two pounds of diluted sulphuric acid be mixed with three pounds of snow, the temperature of the snow will immediately be reduced 55 degrees, or from 32° to −23°.

grees of heat in an instant. Indeed, the rapidity with which the temperature becomes afterwards reduced, would probably be an obstacle to its employment in any of the operations of the laboratory, or in the affairs of common life. I have, however, as a matter of curiosity, constructed the following table of the different temperatures which are produced by mixtures in various proportions of water with this acid[32].

[32] The effect produced by the mixture of sulphuric acid and water is well known; but no writer has noticed the property which heated sulphuric acid has of retaining its caloric, or of imparting it slower than most other fluid bodies usually do. I have observed that the

The temperatures of the water which I employed, and of the atmosphere of the room were at 50°. The acid was the common oil of vitriol of commerce, of the temperature of 56°, and of the specific gravity of 1,844, and fresh oil of vitriol and fresh water were taken for every distinct experiment.

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workmen frequently pour this article from the retorts into large empty glass bottles called carboys, at a temperature of from 190° to 200° without inconvenience; whereas, if water were used at the same, or even at a lower temperature, it would not fail to split them in an instant.

A Table of the temperatures produced by the mixture of sulphuric acid and water.

Weight of water used in each Experim.	Sulph. acid in pounds.	Acquired Temper. of Fahrenht.	Weight of water used in each Experim.	Sulph. acid in pounds.	Acquired Temper. of Fahrenht.
10	1	78°	10	14	236°
pounds	2	100	pounds	15	241
avoirdu-	3	110	avoirdu-	16	246
pois.	4	128	pois.	17	250
	5	138		18	253
	6	144		19	256
	7	156		20	258
	8	168		25	266
	9	186			—
	10	204		27	265
	11	214		*30	264
	12	222		35	258
	13	229		40	248

* An experiment was made with the same proportion of the ingredients in ounces instead of pounds; viz. ten ounces of water were mixed with thirty ounces of sulphuric acid, and though the mixture was made in favourable circumstances, the temperature did not exceed 246 of Fahrenheit.

In making these experiments, I observed that in the two first it required five minutes for the mixture to arrive at the maximum of temperature; that afterwards it acquired the maximum in two minutes; and that when the weight of the sulphuric acid was more than half that of the water with which it was mixed, the heat was evolved with still greater rapidity, till at last the change seemed to be instantaneous.

The accurate performance of these experiments is attended with some difficulty, on account of the steam which arises from the surface of the mixture; for when the weights of the sulphuric acid exceeded those of the water, the steam, in some of the

experiments, was so great as to render it very difficult to determine the exact point to which the mercury had ascended. In the latter experiments, when the weight of the acid amounted to nearly double that of the water, although the temperature occasioned by the mixture of those fluids was higher, little or no vapour was formed, and the graduation of the thermometer could, at each experiment, be observed with exactness.

Fourcroy, in his System of Chemical Knowledge, relates [33] that "the mixture of water and sulphuric

[33] Nicholson's Translation of Fourcroy, vol. ii. page 94.

acid which produces the greatest heat, consists of four parts of acid and one of water, and that the temperature rises to 120° of Reaumur's scale," equal to 302° of Fahrenheit. This statement I find to be incorrect; for the real maximum of temperature is obtained by a mixture of between two and three parts of acid to one of water; and the greatest elevation of temperature which I have been able to procure, is that of 266°. Had the experiments, however, been made in summer, it is probable the temperature might have been raised in some measure higher.

It may be necessary to caution those who have not been accustomed to chemical operations, and yet would

like to repeat these experiments[34], to be careful to add the oil of vitriol to the water, and not to reverse it by pouring the water upon the acid, which would be apt to occasion a part of the mixture to fly up, and endanger the face and the clothes of the operator.

Within these few years past I have been applied to by several persons in different parts of the kingdom, for

[34] As some people may be surprised to see an account of experiments made on so large a scale, and with so great an expenditure of sulphuric acid, it may be advisable just to remark, that, in such a manufactory as mine, diluted sulphuric acid is used for such a variety of processes, that similar experiments can at any time be made without much trouble, or incurring any actual expense.

instructions respecting a mode of ascertaining the quantity of acid in diluted sulphuric acid, and I invariably referred them to Dr. Kirwan's Table, which was published in the year 1793 in the fourth volume of the Transactions of the Royal Irish Academy. This, however, always proved unsatisfactory to those who applied to me, inasmuch as few manufacturers understood how to accommodate that table to the common oil of vitriol, or to make it applicable to any practical purpose. This has arisen from the circumstance of Dr. Kirwan having taken for his standard sulphuric acid as it exists in sulphate of potass, instead of the strongest oil of vitriol of commerce.

Having found the inconvenience of this in my own concerns, I some years ago formed a table for my private use, founded upon the sulphuric acid of commerce, by diluting that acid with several successive portions of water; a table which I have ever since employed with great advantage. But as this table was formed at a temperature above the mean temperature of the atmosphere, and its range was too confined to be of use in every instance, I resolved to undertake the formation of a new one that would be more generally useful, and which should proceed by very slow, but regular gradations, up to the highest point of dilution that any consumer

of sulphuric acid would be likely to require[35].

Having, at no small expense of time and labour, completed this table, it will be inserted in this Essay, from a persuasion that it will prove useful, and consequently very acceptable, to many individuals in various branches of trade and manufacture.

To compose this table, I might have taken *purified* sulphuric acid, *i. e.* such as had undergone an actual distillation; but as this is an article which is never employed but for phi-

[35] The first line of the table shows the specific gravity of a mixture of one part water and 100 parts of strong sulphuric acid. The latter, the specific gravity of one part of sulphuric acid mixed with 100 parts of water.

losophical purposes, I thought it better to make use of the common acid, and to take as good a sample of that kind as could possibly be procured. I therefore chose some of my own manufacture, made in the usual way, and concentrated, as is common in large manufactories, by steaming it in a boiler of lead, and finishing it in a retort of glass. When I began the experiment, the atmosphere of the room was at 60°[36], and the acid was of the specific gravity of 1.8494, which, at this temperature, is as strong as it is ever sold.

[36] For a statement of the difference which is occasioned in the specific gravity of sulphuric acid by change of temperature, consult the table at page 461 of this Essay.

In order to form the annexed table, I proceeded as follows:

I first accurately weighed ten thousand grains of this acid into a stoppered bottle of glass, and then added to it 100 grains of pure water [37]. When the mixture was become cool, after having been sufficiently agitated, the specific gravity of it was taken, and the result forms the first line of the table. In this way I continued to dilute the acid with successive portions of water, taking care to let it rest a sufficient time between

[37] In diluting sulphuric acid, it is usual, and safer, to add the acid by degrees to the water, and not the water to the acid; but with this very small quantity of water, such caution was not necessary.

each addition of the water, that a complete union between the acid and the water might take place; having found by experiment that a mixture of sulphuric acid and water, even after it has become cold, requires several hours to arrive at the maximum of condensation. I took also the precaution of keeping it in stoppered bottles, that it might not imbibe water from the atmosphere, and frequently agitated it during each interval. And, in order to attain as great accuracy as possible, I procured a gravity-bottle larger than usual, one that holds nearly ten ounces of water, and with a stem so small that at the part to which the fluid rises when properly

filled, a single drop of the liquor will occasion a rise of nearly one sixteenth of an inch.

The balance which I made use of in these experiments, is so delicate, that it will turn with the twentieth part of a grain; and as the acids will erode the common scale-dishes, if dropt upon them, and endanger the accuracy of a result, I have long been in the habit of using those made of Wedgwood's ware, and such were employed in making this table. Those parts of the table which have a star opposite to them, were founded on actual experiment; the intermediate ones were the results of calculation.

Since I concluded these experiments it occurred to me, that it might

be useful to some manufacturers to know the quantity of acid per cent, in diluted acid of any given strength; I have therefore calculated the quantity in each, and annexed it. The column of *ounces* and *drachms* is added for the use of those who are accustomed to this mode of reckoning, and also for those who are not conversant with the usual method of stating specific gravities; and it is calculated on the supposition of the wine-pint holding exactly sixteen ounces avoirdupois of pure water.

It is a convenient way of measuring, to have a glass bottle with a narrow neck, holding rather more than a pint of water, with a mark on the stem exactly at the place to

which the water ascends when it contains exactly 16 ounces avoirdupois of that fluid. It was formerly understood that the standard wine-pint was the exact measure of 16 ounces of pure water; but in opposition to a decision made by the Board of Excise in the year 1688, it has since been determined that the English wine-pint holds 7272 grains[38] of pure water, which is 272 grains

[38] If the wine-pint of water, that is, 7272 grains, be divided by 16, this will give 454½ grains for the weight of the ounce measure of water, which, if expressed in decimal figures, will stand thus, 454.5; and it is worth remarking, that there is a singular coincidence here which is very favourable to the memory, *viz.* the pint measure is *seven two, seven two*; and the ounce measure, *four five, four five.*

more than an avoirdupois pound. However, as it has long been usual, for all common purposes, still to consider it of the capacity of 16 ounces avoirdupois, I have taken it at that in the construction of this table.

The sulphuric acid which is consumed in these kingdoms amounts to upwards of three thousand tons annually, of which the greater part is used in a state of dilution. For the purposes of dissolving iron or zinc, it should be diluted with at least five or six times its weight of water. Sulphuric acid is consumed in large quantities by bleachers, for making the oxymuriate of lime, and they always use it in a state of dilution. The calico-printers also ex-

pend large sums in the purchase of this acid, which they use in various states of dilution, for making what they call sours.

To these, and other manufacturers, this table will be of use, not only in assisting them in the formation of acid of any given strength, but it will enable them at any time to ascertain whether their servants have observed due care in making the different preparations, which is a matter of great moment; for, it often happens, that for want of this the printer and manufacturer suffer great loss, and the goods sustain an irreparable injury.

I need scarcely add that the oil of vitriol-makers themselves may also

derive benefit from attending to this table; for, by its assistance, they can at all times form a pretty accurate estimate of the value of any sample of the unrectified acid, or of the weak acid while in the state of operation in any of their lead-houses.

A New Table of the Specific Gravities of Sulphuric Acid, when diluted with different portions of water, constructed for the use of manufacturers; being the result of experiments made with the strongest sulphuric acid of commerce. The specific gravities taken at the temperature of 60°.

	Drachms of Water.	Specific Gravity.	Weight of the Wine Pint.		Acid per Cent.
			Oz.	Drms.	
100 Drachms Sulp. Acid. Sp. Grav. 1·8494, Or, 29 oz. 9¼ Drachms, the Weight, Avoirdupois, of the Wine Pint, reckoning the Pint to hold exactly 16 Ounces of Water.	*1	1·8484	29	9¼	99·009
	*2	1·8465	29	8¼	98·039
	*3	1·8445	29	8¼	97·087
	*4	1·8416	29	7½	96·153
	*5	1·8387	29	6¼	95·238
	6	1·8358	29	6	94·339
	*7	1·8319	29	5	93·457
	8	1·8270	29	3¾	92·509
	9	1·8222	29	2½	91·743
	*10	1·8163	29	1	90·909
	11	1·8104	28	15½	90·090
	12	1·8046	28	14	89·285
	13	1·7988	28	12½	88·495
	14	1·7929	28	11	87·719
	*15	1·7880	28	9¼	86·956

	Drachms of Water.	Specific Gravity.	Weight of the Wine Pint.		Acid per Cent.
			Oz.	Drms.	
100 Drachms Sulp. Acid. Sp. Grav. 1·8494, Or, 29 oz. 9½ Drachms, the Weight, Avoirdupois, of the Wine Pint, reckoning the Pint to hold exactly 16 Ounces of Water.	16	1·7821	28	8	86·206
	17	1·7744	28	6¼	85·470
	18	1·7666	28	4¼	84·745
	19	1·7588	28	2¼	84·033
	20	1·7510	28	0¼	83·333
	*21	1·7431	27	14¼	82·644
	22	1·7353	27	12¼	81·967
	23	1·7275	27	10¼	81·300
	24	1·7207	27	8½	80·645
	25	1·7138	27	6¼	80·000
	26	1·7070	27	5	79·365
	*27	1·7002	27	3¼	78 740
	28	1·6933	27	1½	78 125
	29	1·6865	26	15¼	77·519
	30	1·6796	26	14	76·923
	31	1·6728	26	12¼	76·335
	32	1·6660	26	10½	75·757
	*33	1·6582	26	8½	75·187
	34	1·6523	26	7	74·626
	35	1·6464	26	5½	74 074
	36	1·6406	26	4	73·529
	37	1·6348	26	2½	72 992
	38	1·6289	26	1	72·463
	39	1·6230	25	15½	71·942
	*40	1·6171	25	14	71·428

	Drachms of Water.	Specific Gravity.	Weight of the Wine Pint.		Acid per Cent.
			Oz.	Drms.	
100 Drachms Sulp. Acid. Sp. Grav. 1·8494, Or, 29 oz. 9½ Drachms, the Weight, Avoirdupois, of the Wine Pint, reckoning the Piut to hold exactly 16 Ounces of Water.	41	1·6113	25	12½	70·921
	42	1·6054	25	11	70·422
	43	1·5995	25	9½	69·930
	44	1·5937	25	8	69·444
	*45	1·5879	25	6½	68·965
	46	1·5820	25	5	68·493
	47	1·5761	25	3½	68 027
	48	1·5703	25	2	67·567
	49	1·5645	25	0½	67·114
	50	1·5585	24	15	66·666
	51	1·5526	24	13½	66·225
	52	1·5478	24	12¼	65·789
	53	1·5429	24	11	65·359
	*54	1·5390	24	10	64·935
	55	1·5351	24	9	64·516
	56	1·5312	24	8	64·102
	57	1·5273	24	7	63·694
	58	1·5234	24	6	63·291
	59	1·5195	24	5	62·893
	60	1·5156	24	4	62·500
	61	1·5117	24	3	62·111
	*62	1·5078	24	2	61·728
	63	1·5039	24	1	61·349
	64	1·5000	24	0	60·975
	65	1·4960	23	15	60·606

	Drachms of Water.	Specific Gravity.	Weight of the Wine Pint. Oz.	Drms.	Acid per Cent.
100 Drachms Sulp. Acid. Sp. Grav. 1·8494, Or, 29 oz. 9½ Drachms, the Weight, Avoirdupois, of the Wine Pint, reckoning the Pint to hold exactly 16 Ounces of Water.	66	1·4921	23	14	60·240
	67	1·4882	23	13	59·880
	68	1·4843	23	12	59·523
	69	1·4804	23	11	59·171
	*70	1·4765	23	10	58·823
	71	1·4726	23	9	58·481
	72	1·4687	23	8	58·139
	73	1·4648	23	7	57·803
	74	1·4609	23	6	57·471
	75	1·4570	23	5	57·142
	76	1·4531	23	4	56·818
	77	1·4502	23	3¼	56·497
	*78	1·4473	23	2½	56·179
	79	1·4433	23	1½	55·865
	80	1·4395	23	0½	55·555
	81	1·4365	22	15¼	55·248
	82	1·4336	22	15	54·945
	83	1·4306	22	14¼	54·644
	84	1·4276	22	13½	54·347
	85	1·4257	22	12¼	54·054
	*86	1·4218	22	12	53·763
	87	1·4189	22	11¼	53·475
	88	1·4160	22	10½	53·191
	89	1·4130	22	9¼	52·910
	90	1·4101	22	9	52·631

	Drachms of Water.	Specific Gravity.	Weight of the Wine Pint. Oz.	Drms.	Acid per Cent.
100 Drachms Sulp. Acid. Sp. Grav. 1·8494, Or, 29 oz. 9½ Drachms, the Weight, Avoirdupois, of the Wine Pint, reckoning the Pint to hold exactly 16 Ounces of Water.	91	1·4072	22	8½	52·356
	92	1·4042	22	7½	52·083
	93	1·4013	22	6¼	51·813
	*94	1·3984	22	6	51·546
	95	1·3955	22	5¼	51·282
	96	1·3926	22	4½	51·020
	97	1·3906	22	4	50·761
	98	1·3886	22	3½	50·505
	99	1·3867	22	3	50·256
	*100	1·3848	22	2½	50·000
	105	1·3730	21	15½	48·780
	*110	1·3632	21	13	47·619
	115	1·3535	21	10½	46·511
	*120	1·3437	21	8	45·454
	125	1·3359	21	6	44·444
	*130	1·3281	21	4	43·478
	135	1·3203	21	2	42·553
	*140	1·3125	21	0	41·666
	145	1·3056	20	14¼	40·816
	*150	1·2988	20	12½	40·000
	155	1·2919	20	10¾	39·215
	*160	1·2851	20	9	38·461
	165	1·2783	20	7¼	37·735
	170	1·2724	20	5¾	37·037
	175	1·2676	20	4½	36·363

	Drachms of Water.	Specific Gravity.	Weight of the Wine Pint.		Acid per Cent.
			Oz.	Drms.	
100 Drachms Sulp. Acid. Sp. Grav. 1·8494, Or, 29 oz. 9½ Drachms, the Weight, Avoirdupois, of the Wine Pint, reckoning the Pint to hold exactly 16 Ounces of Water.	*180	1·2627	20	3¼	35·714
	185	1·2568	20	1¾	35·087
	190	1·2520	20	0½	34·482
	195	1·2470	19	15¼	33·898
	*200	1·2421	19	14	33·333
	210	1·2343	19	12	32·258
	*220	1·2265	19	10	31·250
	230	1·2187	19	8	30·303
	*240	1·2129	19	6½	29·411
	250	1·2060	19	4¼	28·571
	*260	1·1992	19	3	27·777
	270	1·1933	19	1½	27·027
	*280	1·1875	19	0	26·315
	290	1·1825	18	14¾	25·641
	*300	1·1776	18	13½	25·000
	310	1·1728	18	12¼	24·390
	320	1·1679	18	11	23·809
	330	1·1630	18	9¾	23·255
	*340	1·1582	18	8½	22·727
	350	1·1552	18	7¼	22·222
	360	1·1523	18	7	21·739
	370	1·1494	18	6¼	21·276
	*380	1·1464	18	5½	20·833
	390	1·1426	18	4½	20·408
	400	1·1338	18	2¼	20·000

	Drachms of Water.	Specific Gravity.	Weight of the Wine Pint.		Acd per Cent.
			Oz.	Drms.	
100 Drachms Sulp. Acid. Sp. Grav. 1·8494, Or, 29 oz. 9½ Drachms, the Weight, Avoirdupois, of the Wine Pint, reckoning the Pint to hold exactly 16 Ounces of Water.	*420	1·1328	18	2	19·230
	440	1·1279	18	0¼	18·518
	*460	1·1240	17	15¼	17·857
	480	1·1181	17	14¼	17·241
	*500	1·1132	17	13	16·666
	*550	1·1054	17	11	15·384
	*600	1·0966	17	8¼	14·285
	*650	1·0898	17	7	13·333
	*700	1·0839	17	5½	12·500
	*750	1·0781	17	4	11·764
	*800	1·0732	17	2¼	11·111
	*850	1·0693	17	1¼	10·526
	*900	1·0664	17	1	10·000
	*950	1·0625	17	0	9·523
	*1000	1·0602	16	15½	9·090
	*1100	1·0546	16	14	8·333
	*1200	1·0507	16	13	7·692
	*1300	1·0488	16	12½	7·142
	*1400	1·0458	16	11¼	6·666
	*1500	1·0429	16	11	6·250
	1600	1·0390	16	10	5·882
	1700	1·0370	16	9½	5·555
	*1800	1·0351	16	9	5·263
	1900	1·0337	16	8⅝	5·000
	*2000	1·0322	16	8¼	4·761

	Drachms of Water.	Specific Gravity.	Weight of the Wine Pint.		Acid per Cent.
			Oz.	Drms.	
100 Drachms Sulp. Acid. Sp. Grav. 1·8494, Or, 29 oz. 9½ Drachms, the Weight, Avoirdupois, of the Wine Pint, reckoning the Pint to hold exactly 16 Ounces of Water.	*2250	1·0283	16	7¼	4·255
	*2500	1·0254	16	6½	3·846
	*2750	1·0234	16	6	3·508
	*3000	1·0214	16	5½	3·225
	*3500	1·0185	16	4¾	2·777
	*4000	1·0166	16	4¼	2·439
	*4500	1·0146	16	3¾	2·173
	*5000	1·0127	16	3¼	1·960
	5500	1·0117	16	3	1·785
	*6000	1·0107	16	2¾	1·639
	6500	1·0102	16	2⅝	1·515
	*7000	1·0098	16	2½	1·408
	7500	1·0093	16	2⅜	1·315
	*8000	1·0088	16	2¼	1·234
	8500	1·0083	16	2⅛	1·162
	*9000	1·0078	16	2	1·098
	9500	1·0073	16	1⅞	1·041
	*10000	1·0068	16	1¾	0·990

This table was compiled in the year 1812, and printed in the Philosophical Magazine for the September

of that year; but since its publication I have been informed there is a table by Vauquelin, in one of the volumes of the Annales de Chimie, on a similar plan. To this I have referred, and on comparison[39], allowing for the difference in the strength of the acid which we severally employed, I find that his table and mine very nearly coincide, except in one instance, and in this there is a material disagreement.

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[39] It may be proper to remark, that the table by Vauquelin is a very confined one, and gives only twelve examples of the specific gravity of diluted sulphuric acid; while mine on the contrary contains no less than 183 such examples.

I have stated that the diluted acid of the spec. grav. of 1·023 contains only 3·508 per cent. of the strongest sulphuric acid of commerce, whereas he says it contains 6·600 per cent. of acid and 93·400 of water. This has induced me to repeat so much of the experiment as was necessary for satisfaction on this point, and I find that this repetition only confirms the accuracy of the foregoing table.

However, as the sulphuric acid which Vauquelin employed had a spec. grav. only of 1·8420, I procured some acid exactly of the same strength; and having carefully mixed 66 drachms of it with 934 drachms of pure water, both measured by

weight, and left the mixture at rest a proper time for a complete combination to be effected, I found its spec. grav. at 60° of Fahrenheit to be 1·0474 instead of 1·0230 as Vauquelin has stated. Pursuing the experiment still further, I found that 66 drachms of such acid, instead of taking 934 drachms of water, actually require 2084 drachms of that fluid to reduce the acid to the specific gravity in question, viz. that of 1·023.

As the foregoing table proceeds entirely on the dilution of the concentrated sulphuric acid with different portions of water, it will not be misplaced if I add a caution respecting the *keeping* of this acid in

a state of dilution, which in certain cases is highly dangerous.

Some years ago, being in conversation with a sulphuric acid-maker, I inadvertently remarked that this acid might be rendered colourless and pellucid without submitting it to the process of rectification in glass, and mentioned how the thing might be effected.

Delighted with this intelligence, on his return home he immediately put the process to the test, without having previously communicated his intention, and actually prepared more than one hundred carboys of this weak acid in readiness to be sent off to customers whom he had hitherto supplied with the usual sulphuric

acid of commerce, and who would not, as he imagined, perceive the difference.

But, unfortunately for this crafty individual, it was in the midst of winter when this grand scheme of sophistication was adopted, and every carboy which he had prepared became frozen. Bottle after bottle, therefore, burst by the expansion of the acid in the act of freezing; and if he had not adopted the method of filling all the large vessels on the premises with tepid water, and immersing the packed carboys in it, not a single bottle would have been saved from the general wreck.

To prevent such accidents, it cannot be too generally known, that sul-

phuric acid diluted to the specific gravity of 1·780, which is twenty-eight ounces and a half to the wine-pint, will freeze *much sooner* than water. If 12 or 13 per cent. of water be mixed with the strong sulphuric acid of commerce, it will form an acid of about the spec. grav. mentioned above, and such acid would freeze at some degrees of temperature higher than that at which water congeals [40].

It was known to many of the old chemists that concentrated sulphuric

[40] If the liquid acid be of greater or less specific gravity, so as to contain even one per cent. more or less real acid, in that case it cannot be frozen in a temperature above 32°. Dalton, page 406.

acid would congeal at a very low temperature; but this very curious and singular property of sulphuric acid was first noticed in this country by Mr. Keir [41].

The affinities of this acid are in the following order:

Barytes,
Strontian,
Potass,
Soda.

The boiling point of the best sulphuric acid of commerce, according to Mr. Dalton, on whom the utmost reliance may be placed, is 590° of Fahrenheit [42].

In a commercial point of view,

[41] Phil. Transactions for 1787.

[42] Dalton's Chemical Philosophy, page 404.

and for every purpose of philosophical chemistry, it is of importance to become acquainted with the variations in the specific gravity of this acid in consequence of change of temperature. I know, however, of no one except Kirwan who has given any information on the subject; and in my opinion he has been peculiarly unfortunate in having made choice of *diluted* acid for his experiments, instead of the concentrated acid[43]. For, to most persons, and especially those who are large buyers of sulphuric acid, it must surely be of

[43] The account of these experiments by Dr. Kirwan, may be seen in Nicholson's quarto Journal, vol. iii. page 211.

more importance to know what the strong sulphuric acid of commerce ought to be in all the variety of temperatures to which this climate is liable. To supply this desideratum, I undertook a series of experiments with such acid, and the several results have enabled me to construct the following table; which, in order that it might embrace every possible exigency, has been extended to 192 degrees of temperature.

A Table of the Variations in the Specific Gravity of concentrated Sulphuric Acid, by change of Temperature, Barometer 29·5 inches.

Temperature according to Fahr.	Contents in Grains, of a bottle holding 4266 grains of pure water, at 42·5 deg. of Fahr.	Specific Gravities.
10°	8000	1·8752
20	7964	1·8668
24	7952	1·8640
27	7940	1·8612
30	7932	1·8593
32	7920	1·8565
36	7912	1·8546
38	7906	1·8532
40	7904	1·8527
42	7901	1·8520
44	7898	1·8522
46	7895	1·8519
48	7892	1·8517
52	7886	1·8511
56	7880	1·8501
60	7864	1·8468
63	7854	1·8449
68	7846	1·8435

Temperature according to Fahr.	Contents in Grains, of a bottle holding 4266 grains of pure water, at 42·5 deg. of Fahr.	Specific Gravities.
70°	7842	1·8430
74	7833	1·8413
80	7816	1·8381
84	7794	1·8343
88	7788	1·8346
92	7780	1·8349
96	7772	1·8343
102	7748	1·8308
108	7729	1·8280
112	7720	1·8267
120	7710	1·8270
126	7702	1·8277
134	7692	1·8279
140	7676	1·8280
146	7648	1·8248
154	7632	1·8258
162	7610	1·8240
170	7582	1·8225
178	7567	1·8233
184	7558	1·8247
192	7546	1·8271

It should be stated, that in forming this table, the low degrees of temperature were produced by immersing a vessel containing the sulphuric acid in a frigorific mixture of snow and muriate of soda; and that the high temperatures were obtained by gradually heating the gravity bottle containing the same acid, before a common fire. Some allowance must therefore be made for the contraction and expansion of the glass, and which would, in some measure, alter the capacity of the containing vessel; but this is unavoidable. In each experiment the acid was poured from the phial, and thoroughly mixed, in order to be sure that the temperature

was uniform before the thermometer was immersed in it.

From these experiments it appears that a vessel capable of containing 8000 grains of concentrated sulphuric acid at 10° of Fahrenheit, will hold only 7546 grains of this acid if at the temperature of 192°, and that sulphuric acid which is of the specific gravity of 1.8752 at 10°, will become of the specific gravity of 1,8271 when brought within 20 degrees of the temperature of boiling water.

It must however be remarked, that the chief design in constructing this table was to furnish the buyers and sellers of sulphuric acid with a scale

by which they might ascertain the proper specific gravity of this acid at all temperatures. For instance, 1.845 is well known to be the proper strength at the temperature of 63°; but by the inspection of this table it will appear, that, when the atmosphere has for some time been at the temperature of 36°, such acid must be deficient in strength if it does not reach the specific gravity of 1.8546.

It has been ascertained that the maximum density of water is at the temperature of 42° 5, and that it becomes specifically lighter, whether it be heated above, or cooled below that point. In making the foregoing table, therefore, it was necessary, in the first place, to fix the weight of

the bottle of pure water at the temperature of 42° 5. This I found to be 4266 grains, and this I made the divisor in every case from 10° up to 42° inclusive. After this, the weight of the water was taken at 44°, and at every other degree between that and 192°; and in calculating the specific gravity of the sulphuric acid at 44°, and at all the higher temperatures, the weight of the acid in every instance was divided by the weight of the same measure of water at the corresponding temperature. This method of constructing the table (and I could not devise any other that would not have presented still greater difficulties) will account for several anomalies in the specific gravities of

the acid when heated above 84°. For instance, the acid at 96° appears to have the same relative weight as at the temperature of 84°; also the acid at 108° and at 140° seem to have the same specific gravity, which cannot in reality be the case. This irregularity can only be accounted for by supposing that sulphuric acid, in its expansion, observes a different law from that of pure water, which, in the formation of this table, as has been before noticed, was made the divisor in every instance [44].

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[44] A new table of the expansion of water by increase of temperature, will be given in one of the subsequent volumes of this work, in the Essay on Water.

The USES of sulphuric acid are very numerous. It is employed in large quantities, as has been already mentioned, for preparing the bleaching salt; by dyers for dissolving indigo, and for other purposes; by calico-printers for preparing sours[45]; and by the manufacturing and the philosophical chemist, as a test for lead and barytes, and for a great variety of other purposes, some of which only can be enumerated.

The makers of the nitrous and muriatic acids are large consumers of sulphuric acid; as also are the makers of sulphate of zinc, sal ammoniac, phosphate of soda, Glauber, and other

[45] See Essay IV, page 113.

salts; as well as the manufacturers of Roman vitriol, Prussian blue, and some other colours.

Sulphuric acid is likewise employed by some modern farmers in the preparation of their seed-wheat, to prevent what is called the smut[46]; by the people who purify lemon-juice, when united to lime, in order to separate its acid in a crystalline form for the use

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[46] The method of employing sulphuric acid in the preparation of seed-wheat is explained by Mr. James Jennings, in one of the volumes of the Bath Agricultural Papers. I think he recommends the dilution of one gallon of the acid with thirty gallons of water, and when the mixture has become cold, to steep the seed in it for 20 hours, and then to sow it before it is allowed to become dry.

of calico-printers and others[47]; and by the makers of glass to convert the muriate of potash, which is one of their residuums, into sulphate of potass, and which has lately been used by them as a substitute for soda. It is also consumed in large quantities by the makers of tin-plate, by brass-founders, button-makers, japanners and gilders; to all of whom this acid is become absolutely necessary for the removal of the oxide which forms on the surface of the iron or the copper on which they work, and which, if not removed, would prevent or impede all their operations.

Sulphuric acid is likewise a ne-

[47] See the Essay on Citric Acid, vol. iii. p. 11, &c.

cessary article to some paper-makers, to fell-mongers, and to tanners;—it is used in considerable quantities by the modern hatter in the operation of felting [48];—and it may be remarked that refiners use it in the process of stripping metals;—oil-merchants, in refining rape-oil, which it effects by carbonizing the farinaceous matter and the mucilage;—and brewers in fining what is called *gray beer* [49]:—that the professors of pharmacy as well as the chemists are constant customers for sulphuric acid;—that it is employed in making the

[48] See Vol. I. of these Essays, Note 74, page 90.

[49] See Combrune on the Theory and Practice of Brewing, 4to, London, 1762, page 274.

astringent and stomatic water of Rabel [50], and for other purposes of medicine, as well as surgery;—that distillers and rectifiers of ardent spirits consume it in still larger quantities;—that the makers of vinegar use it for the adulteration of that acid;—that many tons are annually consumed in the preparation of liquid blacking;—and that the aëronaut, at every ascension into the atmosphere, requires many hundred weights of sulphuric acid for the formation of the hydrogen gas, which renders the aërial machine buoyant in that subtile medium.

These are some of the principal

[50] See Fourcroy, vol. viii. page 240.

uses of sulphuric acid which have occurred to me while writing this paper; and probably there are many more, some of which are not now present to my memory, and others of which I have no knowledge.

I had an intention of giving an ample detail of the methods to be pursued in erecting a lead-house for the manufacture of sulphuric acid, having preserved every necessary document, and registered every precaution which appeared needful should I have occasion to superintend this business; but when I began to put these materials into form for publication, I found that it would be impossible to render the account useful without entering into the minutiæ of the bu-

siness; and there are really so many things to be attended to in its management, that I was afraid, had I done justice to the subject, this Essay would have extended to a length quite inconsistent with the plan of these volumes; and probably too tedious to be acceptable to the generality of readers who are not actually interested in the manufacture of this acid.

For these reasons, I shall content myself with suggesting a few hints which may prove useful to this class of manufacturers, and with these conclude the Essay.

In the erection of lead-houses, one of the first considerations should be to ascertain the exact height of the

adjoining ground, and then to fix the floor of each house at least two feet above this level. This arrangement has two advantages. The first is this, that when the floor of a leaden chamber is so much elevated above the path-way, any leakage which may be occasioned by a flaw in the bottom will be quickly perceived; and should it ever be required to convey the acid from the chambers along leaden spouts to a distant part of the manufactory, this elevation will allow of a regular fall sufficient for the purpose.

It is convenient to have a small well attached to every leaden chamber, either at one end, or on one side of it, and lined with lead, for the

reception of the acid from the floor of the said chamber. If the floor of such well be sunk two feet below the floor of the lead-house, and its sides rise a little higher than the surface of the liquor ever stands within the body of the house, it will be a useful receptacle; and the additional cost, at the time of erecting a chamber, is not worth consideration. By the removal of a plug, at any time, this small vessel becomes quickly filled with acid; and as its sides rise above the level of the fluid within the chamber, no leakage can ever arise from it. Such an appendage is useful for ascertaining the strength of the acid, or for taking out any quantity of it, without opening the

doors of the chambers, or disturbing the operation during the combustion of the sulphur.

Where plates or dishes of iron are used for supporting the burning sulphur, it is useful to place them at a small distance one above the other in tiers of three each. By such an arrangement the combustion on the lower plates will communicate heat to those immediately above them, and this will very much facilitate the burning of the old stuff, which in a large manufactory is usually mixed in a certain proportion with the fresh materials. It is also prudent to have a sheet of lead firmly suspended in the form of a penthouse over every set of these burning-pans,

to prevent the droppings of the chambers from falling into them and checking the combustion.

I would have also a leaden pipe securely soldered into one side of every house a foot or two above the burning-pans, and furnished with a stop-cock for the occasional admission of atmospheric air[51]. I once had a provision of this kind, where the entrance was through the floor of the chamber, and I considered the contrivance to be at times very

[51] The true theory of the formation of sulphuric acid, by means of nitrous gas and atmospheric air, is well explained by Clement and Desormes in the Annales de Chimie for 1806, and also in the 17th volume of Nicholson's Journal.

advantageous. If such a pipe were furnished with a proper valve, the house would occasionally supply itself with atmospheric air, and that strain which the sides of every leaden chamber experience from the production of a vacuum would in this way be prevented.

I have sometimes thought, that in those houses which have only one door at the end for the admission of the combustible materials, it might be advantageous to affix a high chimney at the opposite end, with a valve that might be opened and shut at pleasure; for, by opening the door of the chamber, and then the valve of the chimney, such a powerful draught would be produced as would

sweeten an oil of vitriol-house in less than half the time which is usually required for this operation: but whether the saving of time would be more than adequate to the extra loss of nitrous gas which this rapid draught would occasion, I am not at present able to determine, and therefore have merely thrown out the hint for the consideration of those who have had sufficient experience to enable them to judge of the probable result.

With respect to the retorting-house, one built *entirely* with bricks is doubtless the best, as the gas from this process soon decays the beams and rafters of one erected in the common way. But wherever it may

be necessary to employ a common building for this purpose, I would recommend it to the proprietor to give every piece of timber that is likely to be exposed to the fumes of the sulphurous gas, several coats of the pyroligneous acid tar, which, at page 274 &c. in this volume, I have proposed for the preservation of wood in general.

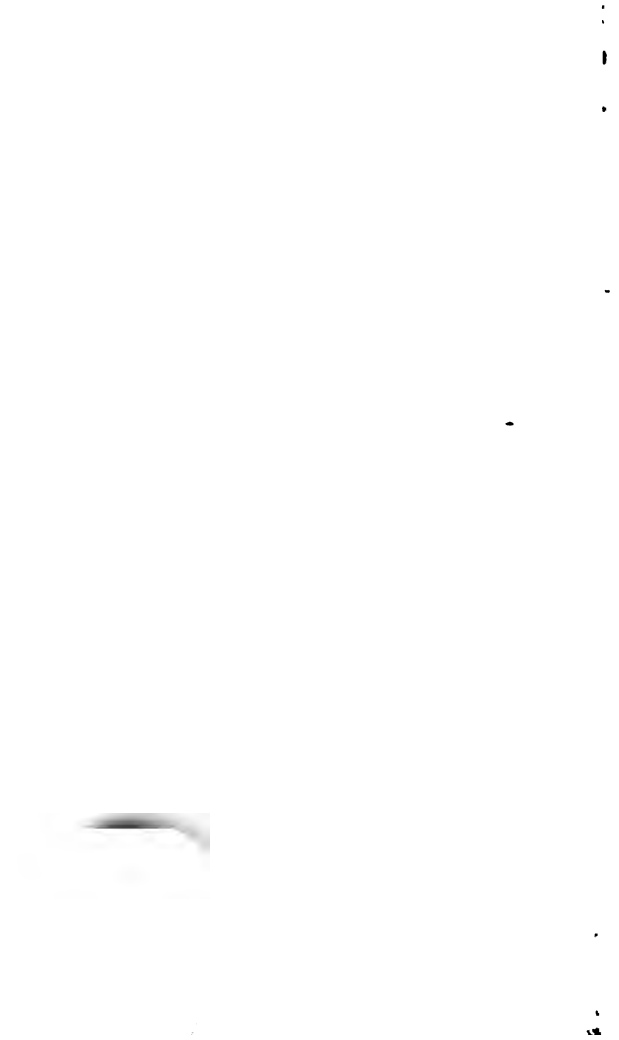
In fixing the beds of retorts, various modes have been adopted by different manufacturers; but I am convinced that no method is so eligible upon the whole as that in which there is a separate and distinct fire for each retort: and when such fireplaces are fitted up with hopper-doors, similar to those described in

vol. i. page 305, the expense of fuel will be infinitely less than by those erected upon any other construction.

In addition to these loose hints, it may be necessary to remark, that no one ought to begin the manufacture of sulphuric acid, or even to erect a lead-house for its preparation, without placing the whole work under the direction of some judicious and experienced person, one who is well acquainted with all the difficulties, and knows how to surmount every obstacle.

It behoves me also, in closing this article, to guard the unwary against engaging in this business, unless it be in their power to embark a large

capital in the concern, and to manufacture sulphuric acid on a great scale. Some individuals may perhaps be disposed to erect a single house to manufacture a quantity sufficient merely for their own consumption; but the expense of working a single chamber, with that of attending the steaming vessel day and night, and afterwards of concentrating the acid in glass, will absorb all the profit. This I can assert with confidence; for it is not merely a matter of opinion, but the actual result of my own experience.

END OF THE SECOND VOLUME.

Printed by Richard & Arthur Taylor, Shoe-lane, London.